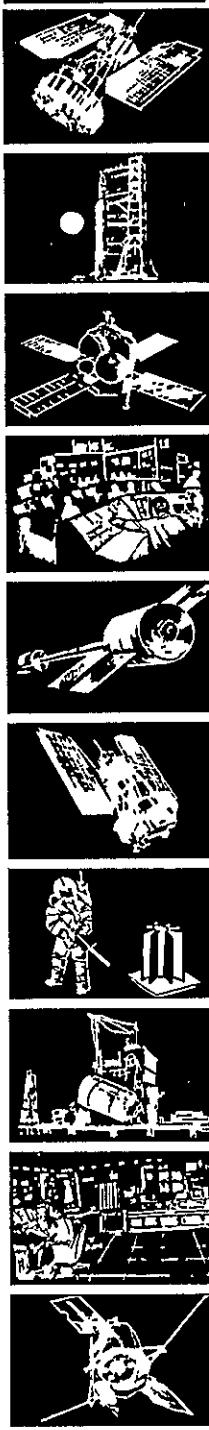


28 JANUARY 1976

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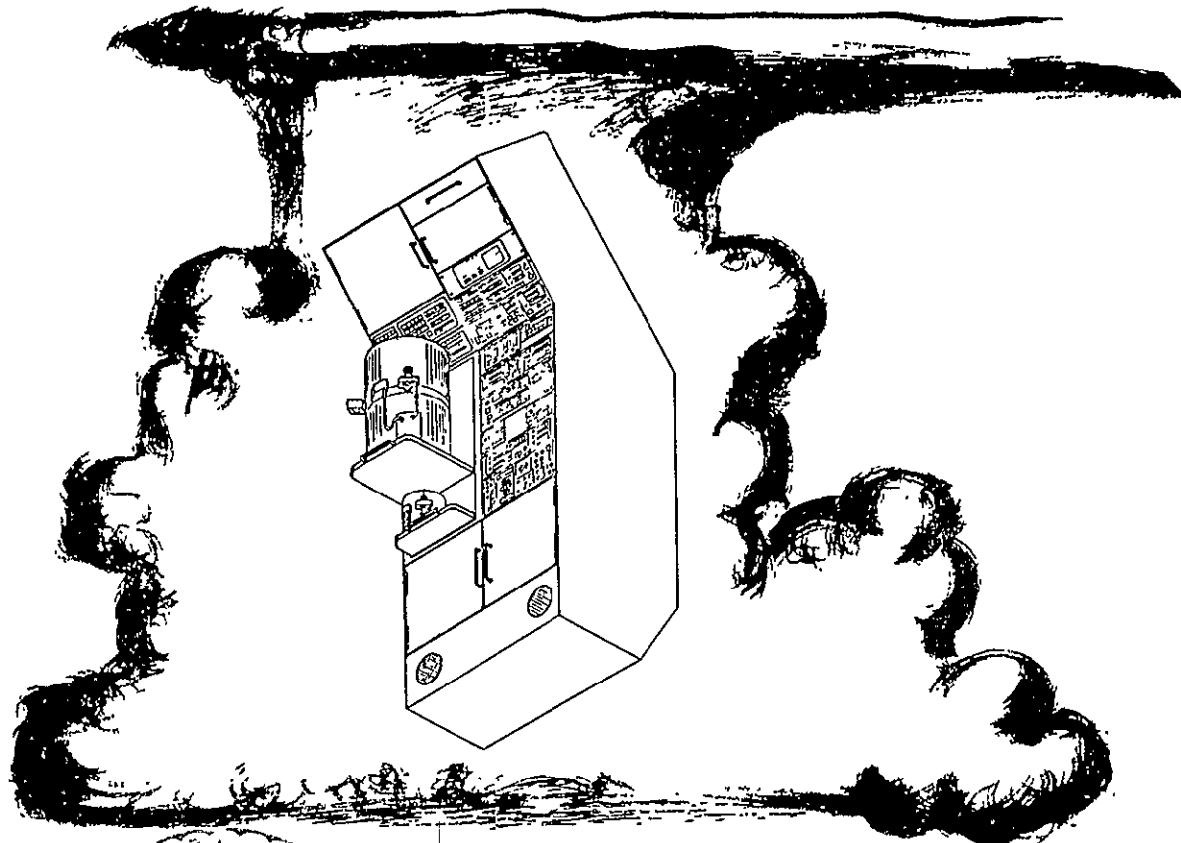


Final Definition And Preliminary Design Study for The Initial

ATMOSPHERIC CLOUD PHYSICS LABORATORY

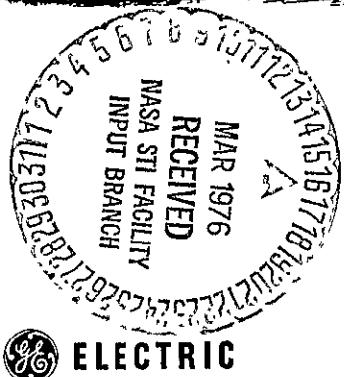
A Spacelab Mission Payload

NAS 8-31845



ORIENTATION MEETING PRESENTATION

DR-MA-03



GENERAL  ELECTRIC

(NASA-CR-144188) FINAL DEFINITION AND
PRELIMINARY DESIGN STUDY FOR THE INITIAL
ATMOSPHERIC CLOUD PHYSICS LABORATORY, A
SPACELAB MISSION PAYLOAD (General Electric
Co.), 144 p HC \$6.00

CSCL 14B G3/19

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N76-18226

28 JANUARY 1976

FINAL DEFINITION AND PRELIMINARY DESIGN
STUDY

FOR THE INITIAL ATMOSPHERIC CLOUD PHYSICS LABORATORY -
A SPACELAB MISSION PAYLOAD
NAS 8-31845

ORIENTATION MEETING
PRESENTATION

DR-MA-03

For
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

by

GENERAL  ELECTRIC
SPACE DIVISION
Valley Forge Space Center
P O Box 8555 • Philadelphia, Penna. 19101

ATMOSPHERIC CLOUD PHYSICS LABORATORY

The Orientation Meeting effort performed by General Electric for the ACPL Phase B Study will consist of the following:

Introduction }
Proposed Configuration } Robert Greco
Study Plan Overview }
ACPL Scientific Requirements - Dr. Larry Eaton
Thermal Control and Data Management Technical Discu

The material contained in this document and presented at the Orientation Meeting conducted at MSFC on 28 January 1976 was formulated to provide a reference "point-of-departure" for the ACPL Phase B Study.



**ATMOSPHERIC
CLOUD
PHYSICS
LABORATORY**

Final Definition and Preliminary Design Study

**Orientation Meeting
January 28, 1976**

SECTION 1
INTRODUCTION

ATMOSPHERIC SCIENCE AT GENERAL ELECTRIC

The General Electric Company has, for the past 35 years, played a major role in the development of cloud physics. From micro to macro-physical cloud processes, the Company has been involved in some of the key theoretical and experimental programs. From aircraft to spacecraft the Company has provided effective, low cost hardware that has helped to further our understanding of clouds and weather. A brief chronology of GE's role in the history of cloud physics is presented below.

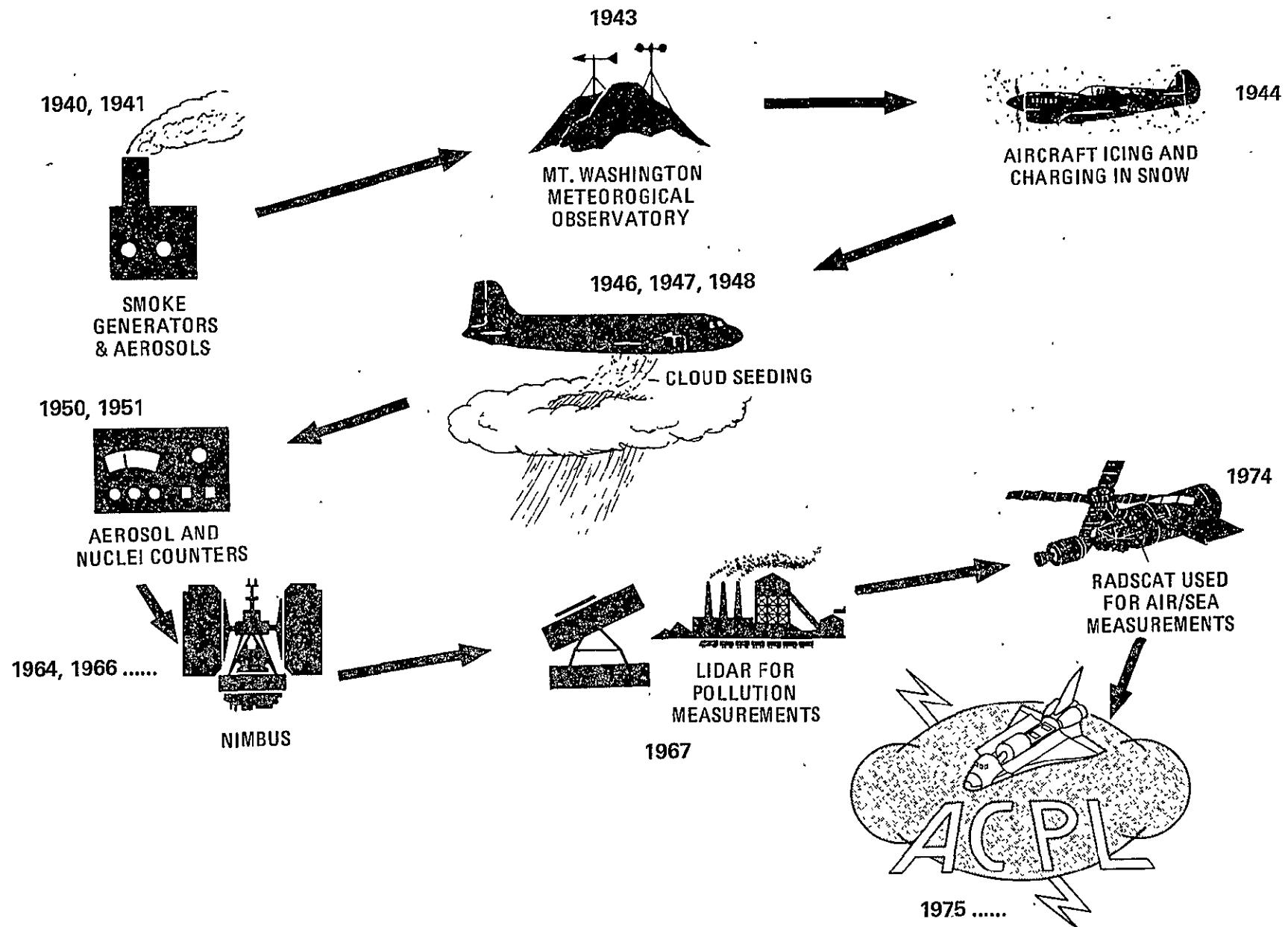
1940	Initial work of Langmuir and Schaefer on filtration of aerosols.	1951	Development of hot wire aerosol detector.
1941	Controlled size smoke generators developed.	1964	Launch of the GE built Nimbus 1 weather satellite.
1943	Langmuir and Schaefer set up meteorological observation on Mt. Washington to study electrostatic charging of aircraft in snow.	1966	Nimbus 2 successfully launched.
1944	Aircraft icing included in research program.	1967	GE markets portable Raman Lidar for pollution measurements.
1946	Schaefer demonstrates supercooled nucleation by dry ice in the laboratory.	1968	Nimbus 3 successfully launched.
1946	Vonnegut demonstrates that silver iodide can be used for cloud seeding.	1969	GE markets a Continuous Portable Nuclei Counter.
1946	First man-made snow storm seeded with dry ice from an aircraft.	1969	Nimbus 2 mission terminated after 33 months of operation.
1947	Project Cirrus initiated under tri-service sponsorship.	1970	Nimbus 4 successfully launched.
1947	Predicted holes produced in stratus clouds by seeding.	1971	GE built polarimeter used to measure aerosol concentration from aircraft.
1949	Modification of large cumulus clouds by single pellets of dry-ice demonstrated	1972	Nimbus 3 mission terminated after 33 months of operation.
1949	Importance of sea salt nucleation on tropical rain demonstrated.	1972	Nimbus 5 successfully launched.
1949	Vonnegut demonstrates the effectiveness of ground based silver iodide generator in causing precipitation.	1974	GE built Microwave Radiometer/Scatterometer used on Skylab to measure air/sea interactions.
1950	Construction of the first continuous Recording Condensation Nuclei Meter.	1975	GE gets contract for Radiometer/Scatterometer on Space Shuttle.
		1975	Nimbus 6 successfully launched. Nimbus 4 and 5 still operational.
		1976	GE plans role in Atmospheric Cloud Physics Laboratory on Space Shuttle.

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ATMOSPHERIC SCIENCE AT GENERAL ELECTRIC 35 YEARS OF EXPERIENCE



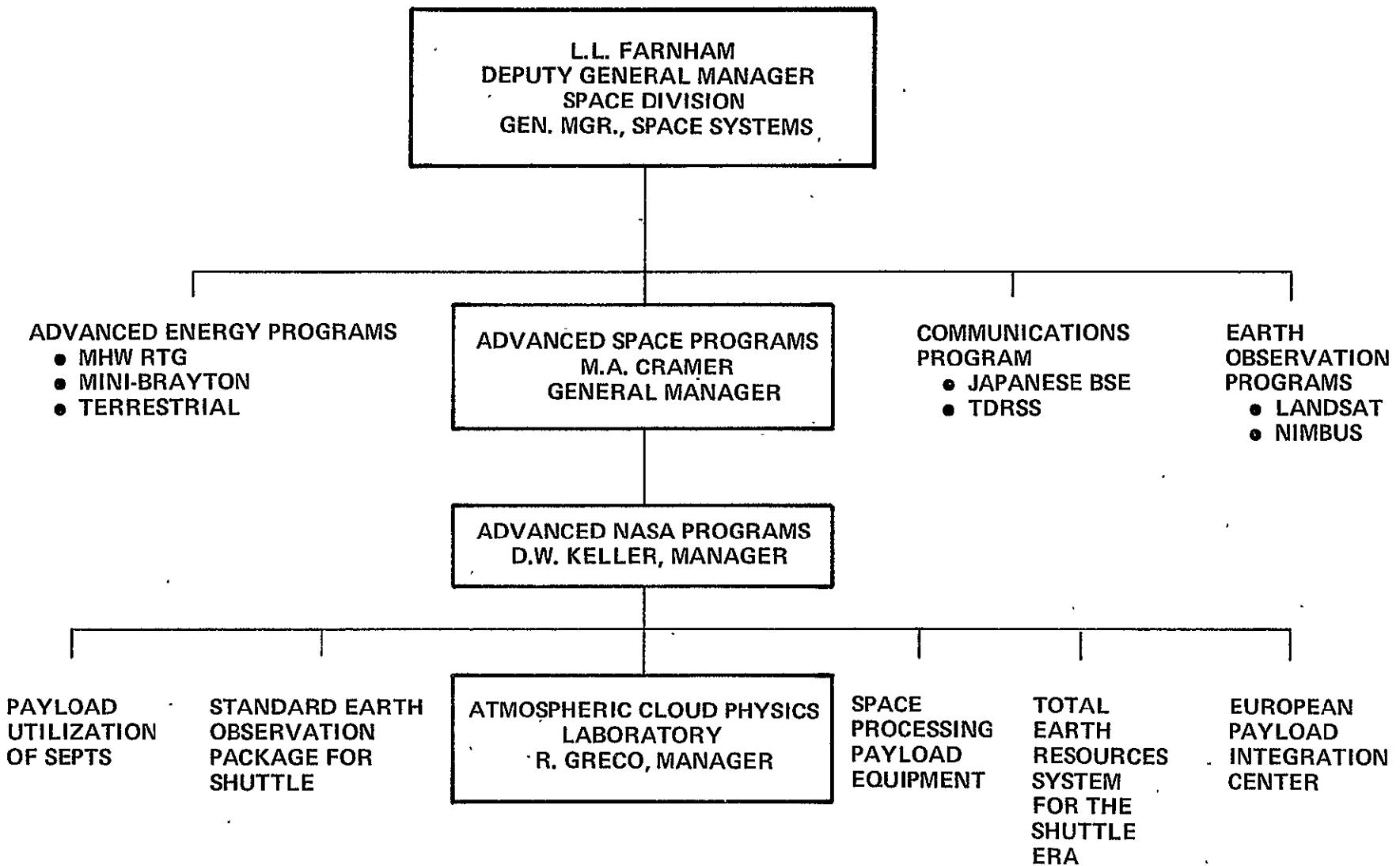
ORGANIZATIONAL POSITION OF STUDY

The Atmospheric Cloud Physics Laboratory (ACPL) Definition Study will be performed in Lee Farnham's 3,000-man Space Systems Organization, which is the General Electric Space Division component specifically organized for the development and manufacture of complex space systems, subsystems, and experiment payloads. Space Systems has had a major segment of its business over the years in designing and building hardware of the size and scope of ACPL.

Within Space Systems' \$100 million a year sales base, Dave Keller's Group, Advanced NASA Programs, under M. A. Cramer, Jr., General Manager, Advanced Space Programs, is responsible for all advanced NASA efforts, and specifically for GE's pursuit of Shuttle payload hardware opportunities. Currently, this group is performing on such programs as the Space Processing Payload Equipment Study (SPPE), Payload Utilization of SEPS, Total Earth Resources System for the Shuttle Era, Biomedical Experiments Scientific Satellite, Standard Earth Observations Package for Shuttle (SEOPS), Earth Viewing Applications Laboratory (EVAL), European Payload Integration Center, and various other applicable Shuttle-related contracts.



G.E. SPACE DIVISION - ACPL ORGANIZATIONAL POSITION



ACPL STUDY TEAM

Key Personnel

Bob Greco, ACPL Program Manager, represents GE Space Systems in all aspects of the ACPL program. He is General Electric's single point interface with the MSFC Study Manager throughout the conduct of the study, with full authority and responsibility for all technical, contractual and financial matters on the program. All program actions will be conducted directly between Bob and the MSFC Study Manager.

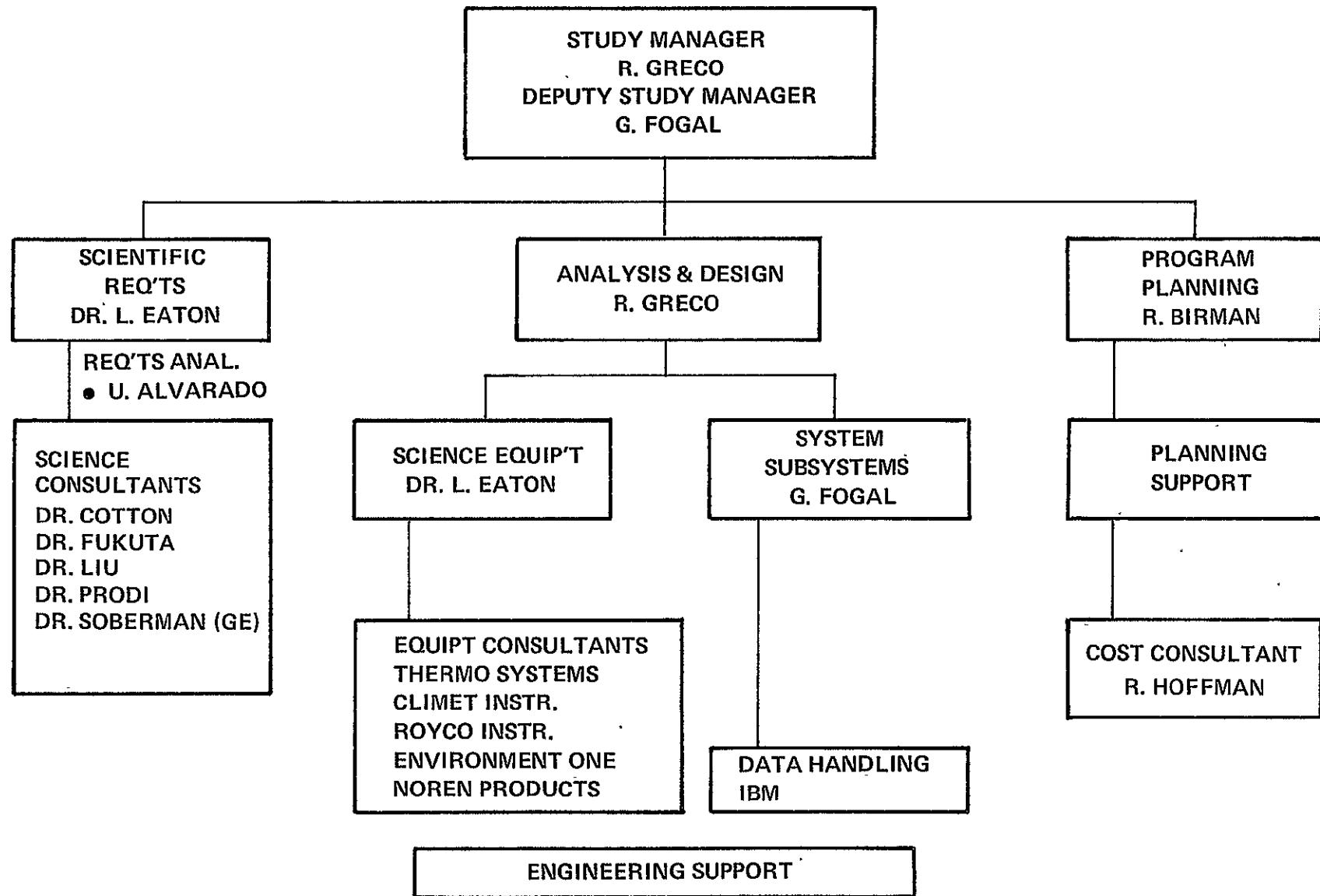
Dr. Larry Eaton, ACPL Program Scientist, will direct all study efforts related to the definition of the laboratory experiment program and scientific equipments, and will coordinate and direct all consulting efforts with the scientific community and equipment manufacturers. He is specifically suited for this position because of his extensive background in cloud microphysics and his experience on prior ACPL study efforts.

Mr. Gordan Fogal, ACPL Chief Engineer and Deputy Program Manager, will be responsible to Bob Greco for defining the initial ACPL design and its adaptability to growth to a full capability ACPL. He will also direct the efforts of our proposed subcontractor, IBM, and serve as Deputy Program Manager in Bob's absence. Gordan has extensive experience in managing, designing and building low cost hardware for GE, and special engineering talent in thermal control and fluid transfer.

Bob Birman, Program Planning, will direct all efforts associated with programmatic analysis and planning which results in lowest total program cost consistent with required technical performance. Bob brings to the study over 20 years of experience in the aerospace field, many of which were spent in developing and implementing programmatrics on major space programs.



GE ACPL STUDY TEAM



TOP LEVEL ACPL SCHEDULE

The attached schedule reflects the present theme of ACPL planning.

Phase B to be completed in '76, and C/D to start in '77, with delivery of the ACPL flight article by December 1977. This ACPL is currently envisioned to be launched aboard the Shuttle/Spacelab in the fall of 1980. As a reusable payload, multiple missions at the rate of approximately 2 per year are envisioned. The enhancement of ACPL capability by the addition of scientific equipment and the improvement of initial equipment performance is planned.



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TOP LEVEL INITIAL ACPL SCHEDULE

	1975	1976	1977	1978	1979	1980	1981	1982
PHASE B (DESIGN)								
PHASE C/D (DEVELOPMENT/ PRODUCTION)					CDR	DELIVERY		
PHASE D (OPERATIONS)							LAUNCHES	
SRT (AD)								
SCIENCE AND APPLICATIONS								
SCIENCE ADVISORY GROUP								
SCIENCE AND APPLICATIONS WORKING GROUP								
EXPERIMENTS								

ACPL STUDY SUMMARY FLOW

The ACPL study consists of eight major tasks as described in the RFP Statement of Work. The relationship of these tasks to each other and to the study performance reviews is shown in the study summary flow. Study documentation and key features of the performance reviews are included.

Task 1 develops scientific functional requirements for the initial and evolutionary cloud physics research program, determines requirements for flight and ground support equipment, and identifies requirements for Supporting Research and Technology (SR&T).

Task 2 addresses two major areas: mission and operations analysis, and systems engineering analysis.

Task 3 analyzes scientific equipment and support subsystems and produces preliminary design drawings and specifications for these items.

Task 4 compiles the results of requirements definition, analyses, and trade studies into Part 1 CEI specifications and functional, physical and procedural ICDs.

Task 5 accomplishes preliminary design of the ACPL, using proposal developed Design Reference Models (DRM's) for the initial ACPL and for evolutionary growth to the full capability ACPL.

Task 6 provides a Work Breakdown Structure and dictionary for use in planning the Phase C/D ACPL program and collecting program costs.

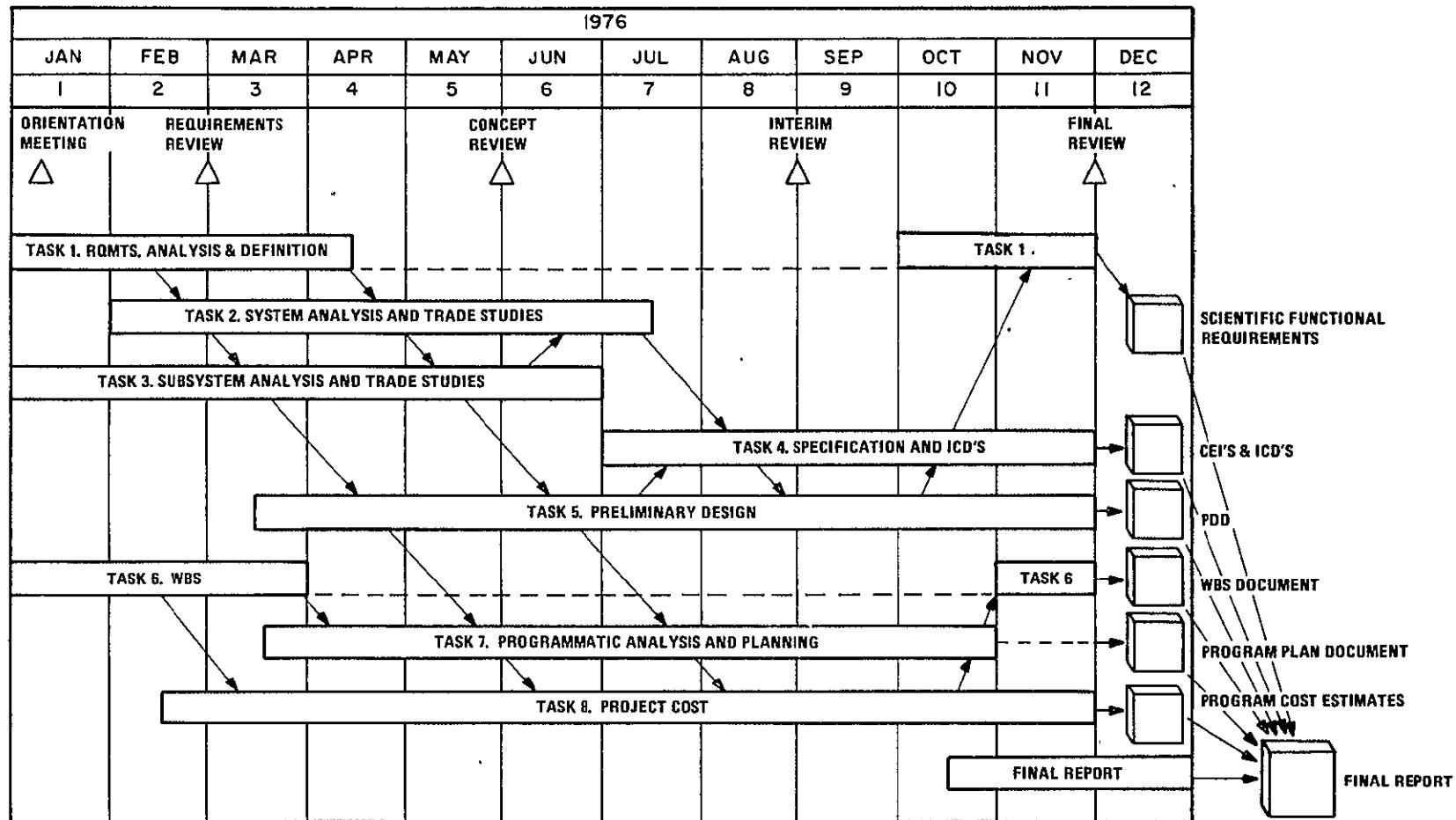
Task 7 integrates the independent task efforts and supplements them by overall ACPL programmatic analyses and planning for each element of the Phase C/D WBS.

Task 8 develops total project costs for the ACPL, with appropriate cost data to WBS level 5.



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ACPL STUDY SUMMARY FLOW



STUDY OUTPUTS

The results of the Atmospheric Cloud Physics Laboratory Phase B Study consist of documents in accordance with contractual data requirements and a contract end item. The data requirements will contain all the necessary study programmatic, design and definition results required to proceed into the ACPL Development and Production effort. The contract end item will be a soft mockup of the Initial ACPL reflecting study results. This mockup will utilize the NASA-MSFC provided standard Spacelab rack.

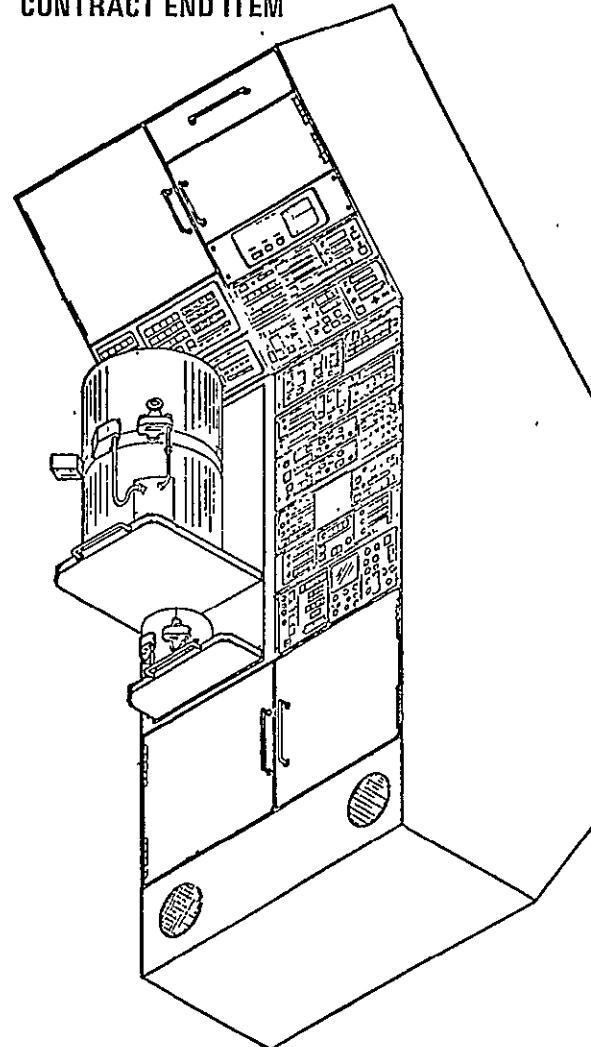


ACPL STUDY OUTPUTS

- DATA REQUIREMENTS

MA-01	STUDY PLAN
MA-02	MONTHLY STATUS REPORTS
MA-03	PERF. REVIEW DOCUMENTS
MA-04	PROG. ANAL. & PLAN DOC.
MA-05	FINAL STUDY REPORT
MA-06	WBS DOCUMENT
MF-003R	PROGRAM COST EST. DOC.
SE-01	PRELIM. DESIGN DOC.
SE-02	I/F CONTROL DOC.
SE-03	SPECIFICATIONS
SE-04	SCI FUNCT. REQ'TS DOC.
SE-243B	SR & T REPORT

- CONTRACT END ITEM



- MOCKUP – INITIAL ACPL

SECTION 2
PROPOSAL CONFIGURATION

PROPOSAL CONFIGURATION

The configurations formulated for the Initial ACPL and its subsequent evolutionary growth will be presented. These configurations are to provide "a-point-of-departure" for the ACPL Phase B Study and were defined to satisfy the RFP objectives identified for the ACPL project. The rationale used for arriving at the baseline configurations was based on providing the broadest experiment scope consistent with the Shuttle/Spacelab capabilities and the programmatic constraints.



PROPOSAL CONFIGURATION

- STUDY OBJECTIVE
- OVERVIEW
- CONCEPT RATIONALE
- BASELINE INITIAL ACPL CONCEPT
 - DESIGN DRIVERS
- EVOLUTIONARY GROWTH
 - CONCEPT
 - CONFIGURATION
- INITIAL ACPL DESIGN FEATURES
 - EXPERIMENT SCOPE
 - MISSION/FLIGHT FLEXIBILITY
 - MODULARITY/COMMONALITY
 - LOW COST APPROACHES

PROTOFLIGHT
S/L CAPABILITY UTILIZATION
EVOLUTIONARY GROWTH

STUDY OBJECTIVE

The primary objective of the ACPL Phase B study is to provide a final definition and a preliminary design of the ACPL as a firm basis for subsequent development, production and operations on early Spacelab missions.

Additionally the study effort is to define an evolutionary growth approach, provide flexibility to accommodate evolving scientific objectives and evaluate all aspects of the program to incorporate realistic low cost approaches.

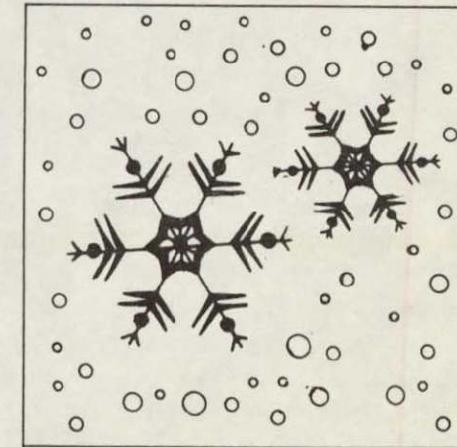
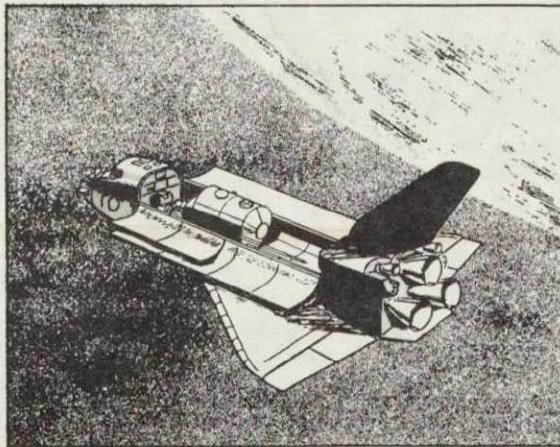
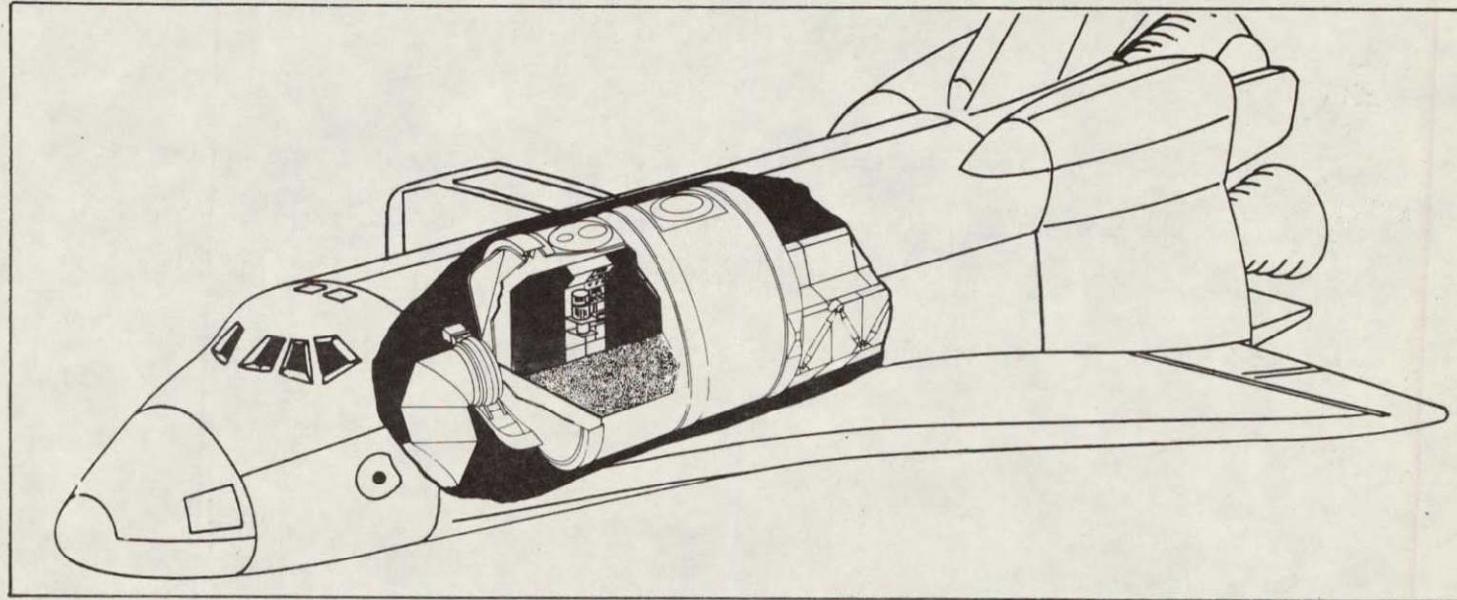


STUDY OBJECTIVE

- FINAL DEFINITION AND PRELIMINARY DESIGN FOR ACPL FOR EARLY SPACELAB MISSIONS
 - EVOLUTIONARY GROWTH
 - WARM CLOUD PROCESSES TO COLD CLOUD PROCESSES
 - SIGNIFICANT EXPERIMENT RESEARCH
 - FLEXIBILITY
 - PERMIT LOW COST APPROACH
 - MAXIMUM RESPONSIVITY TO EVOLVING SCIENTIFIC OBJECTIVES
 - LOW COST APPROACH
 - MAXIMIZE SCIENTIFIC RETURN
 - MINIMIZE COST
 - REALISTIC

ACPL ORBITAL EXPERIMENTATION

The conduct of cloud microphysics research onboard the Shuttle/Spacelab utilizes the primary features of manned orbital flight (near zero gravity and manned operation decision making capability). This partial payload consists of scientific equipment and support equipment mounted in standard Spacelab racks. The reusable ACPL will be selectively configured for individual flights/missions to accomplish the broadest spectrum of scientific research. This research has as its primary objective the accumulation of scientific knowledge to enable man to improve weather prediction and to establish weather modification techniques.



ACPL EXPERIMENT PROGRAM LISTING

The experiment program listing, shown on the facing page, resulted from a comprehensive effort to identify and quantify the orbital experimentation anticipated for the ACPL program. This listing was therefore used as a basis for selecting experimentation for the initial ACPL and the identification of experimentation to be deferred due to complexity, applicability and priority factors.

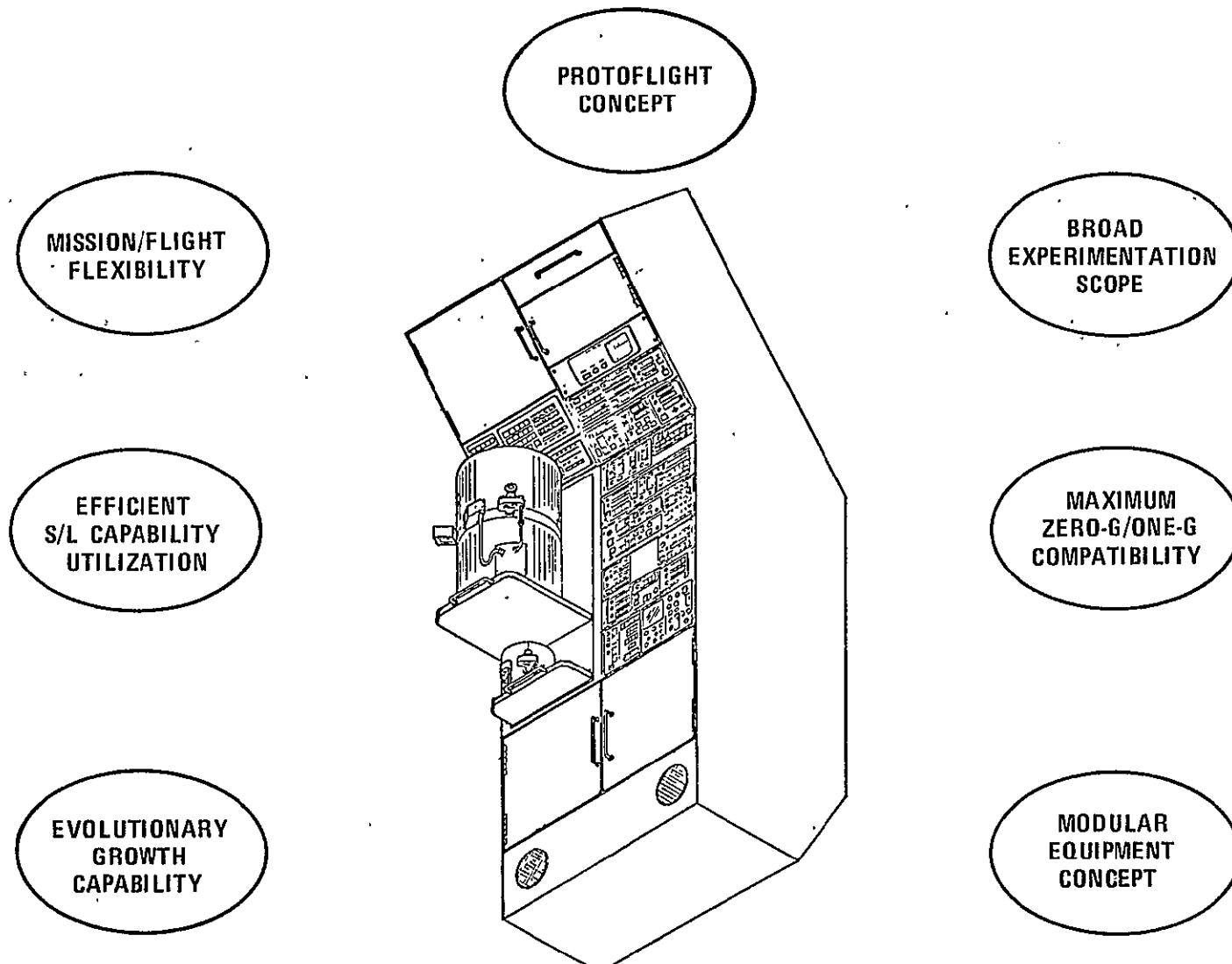


ACPL EXPERIMENT PROGRAM LISTING

EXPERIMENT CLASS NO.	EXPERIMENT CLASS TITLE	DESIGNATION
1	CONDENSATION NUCLEATION	CN
2	ICE NUCLEATION	IN
3	ICE MULTIPLICATION	IM
4	CHARGE SEPARATION	CS
5	ICE CRYSTAL GROWTH HABITS	ICG
6	SCAVENGING	S
7	RIMING AND AGGREGATION	RA
8	DROPLET ICE CLOUD INTERACTIONS	DIC
9	HOMOGENEOUS NUCLEATION	HN
10	COLLISION INDUCED FREEZING	CIF
11	SATURATION VAPOR PRESSURE	SVP
12	ADIABATIC CLOUD EXPANSION	ACE
13	ICE NUCLEI MEMORY	INM
14	TERRESTRIAL EXPANSION CHAMBER EVALUATION	ECE
15	CONDENSATION NUCLEI MEMORY	CNM
16	NUCLEI MULTIPLICATION	NM
17	DROP COLLISION BREAKUP	DCB
18	COALESCENCE EFFICIENCIES	CE
19	STATIC DIFFUSION CHAMBER EVALUATION	SDC
20	UNVENTILATED DROPLET DIFFUSION COEFFICIENTS	UDD

INITIAL ACPL - ISOMETRIC

The Initial ACPL with its primary features and capabilities are shown on the facing page. Broad experiment scope capability is achieved by incorporation of three cloud chambers and related scientific equipment. Efficient Spacelab capability utilization minimizes flight support subsystems for the ACPL. The modular equipment concept provides mission/flight flexibility. The concept is compatible with evolutionary growth either by equipment/subsystem improvement or addition. The protoflight concept with maximum zero g - one g compatibility reduces program cost by reduction of hardware units. These features and capabilities support the attainment of the study and project objectives.



INITIAL ACPL - PRELIMINARY BASELINE

The subsystems and the major equipment complement of each subsystem of the Initial ACPL is shown on the facing page. Two major subsystem categories comprise the ACPL, the Scientific Equipment Subsystems and the Flight Support Subsystems. The functional requirements for the scientific equipment provide the "driver requirements" for the flight support subsystems and subsequently to all other program areas. Consequently in the formulation of the Initial ACPL concept care was exercised in the establishment of scientific equipment requirements to avoid the multiplying effect that results in excessive program cost.



INITIAL ACPL - PRELIMINARY BASELINE

SCIENTIFIC EQUIPMENT SUBSYSTEMS

EXPERIMENT CHAMBERS AND AEROSOL RESERVOIR

- EXPANSION CHAMBER
- CONTINUOUS FLOW DIFFUSION CHAMBER
- STATIC DIFFUSION LIQUID CHAMBER
- AEROSOL RESERVOIR

PARTICLE GENERATORS

- VIBRATING ORIFICE GENERATOR
- EVAPORATOR/CONDENSER GENERATOR
- AEROSOL CONDITIONING ASSEMBLY

PARTICLE DETECTORS AND CHARACTERIZERS

- OPTICAL PARTICLE COUNTER (& PHA)
- CONDENSATION NUCLEI COUNTER (AITKEN)
- ELECTROSTATIC AEROSOL SIZE ANALYZER
- MICROPOROUS FILTER

OPTICAL & IMAGING DEVICES

- CAMERA
- OPTICS
- LIGHT SOURCES

FLIGHT SUPPORT SUBSYSTEMS

THERMAL & FLUID CONTROL

- THERMOELECTRIC COOLER ASSEMBLIES
- HEAT EXCHANGER/COLD PLATE
- MOTOR/PUMP
- COOLANT VALVES
- COOLANT FLUID
- EXPANSION CHAMBER/RESERVOIR
- COOLANT LINES
- GAS PRE-CONDITIONING MODULE
- GAS POST-CONDITIONING MODULE
- HUMIDIFIER
- AEROSOL DILUTER
- MIXER
- VACUUM PUMP
- TUBING
- GAS VALVES

DATA MANAGEMENT

- INTERFACE CONTROL UNIT
- DISPLAY AND CONTROLS

POWER CONDITIONING

- DC/AC CONVERTER
- DC/DC CONVERTER
- REGULATOR - DC/DC CONVERTER
- POWER DISTRIBUTION MODULE
- ELECTRICAL LINES

SUPPORT EQUIPMENT

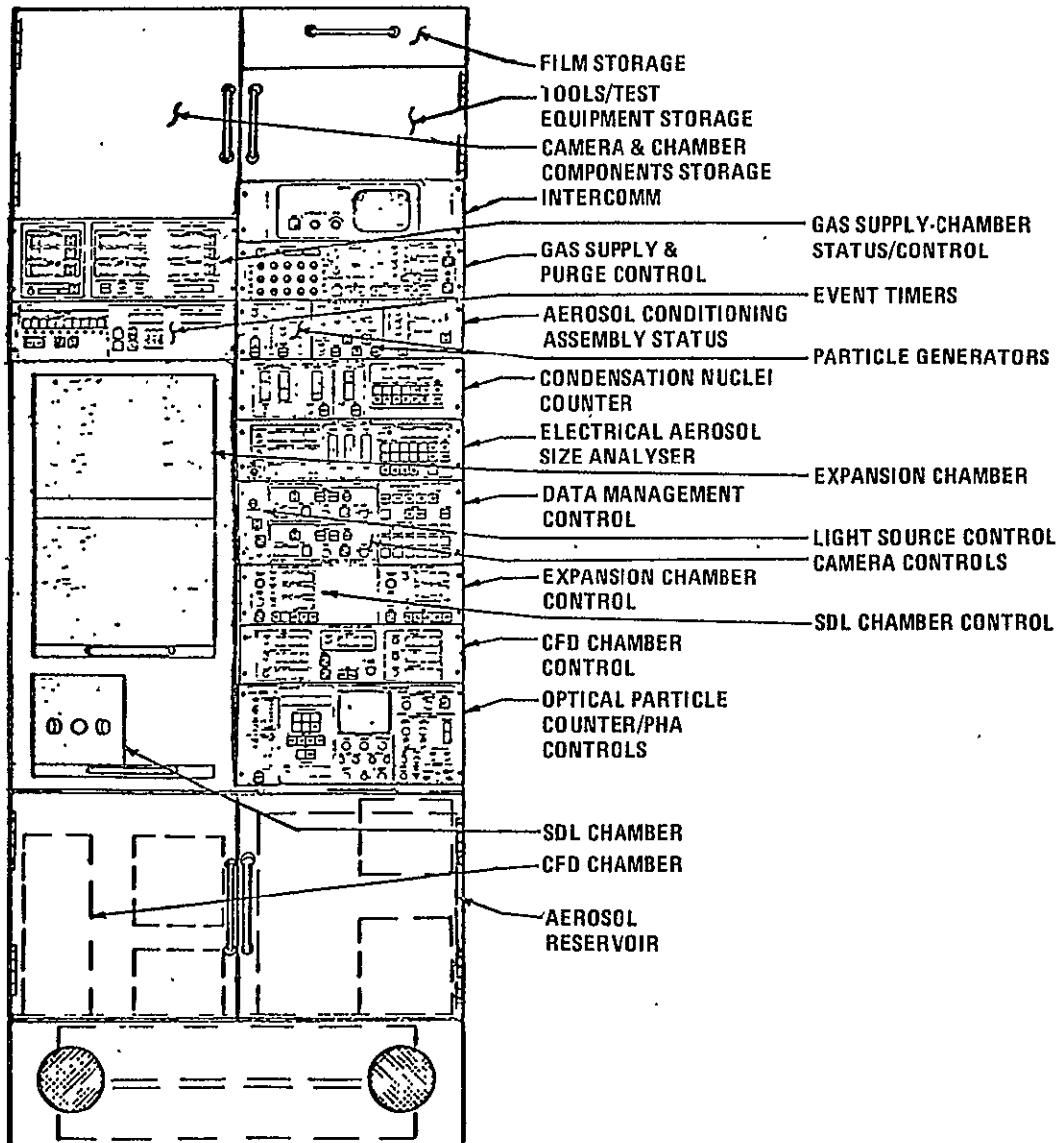
- CONSOLE STRUCTURE
- STORAGE CONTAINERS
- TOOLS/TEST EQUIPMENT

INITIAL ACPL PRELIMINARY BASELINE

The Initial ACPL baseline incorporates features identified at the MSFC Industry Briefing and additional inputs from prominent cloud microphysics researchers. The equipment complement is extensive, including three cloud chambers; Expansion (E), Continuous Flow Diffusion (CFD) and Static Diffusion Liquid (SDL) . The complement of particle generators, particle characterizers and optical and imaging devices, in conjunction with these chambers permits an extensive experimentation capability. This baseline concept furthermore incorporates thermal and fluid control subsystem capability to achieve the desired cold cloud processes, and adaptability for evolutionary growth equipment. The data management subsystem required minimal ACPL hardware and depends primarily on the Spacelab Control and Data Management System (CDMS). Wherever possible modular subsystems concepts were used to facilitate ACPL configuration for specific mission/experiment requirements. This baseline was formulated to assure feasibility of the widest spectrum of cloud microphysics experimentation within the identified 1.06 meter console.

INITIAL ACPL-PRELIMINARY BASELINE

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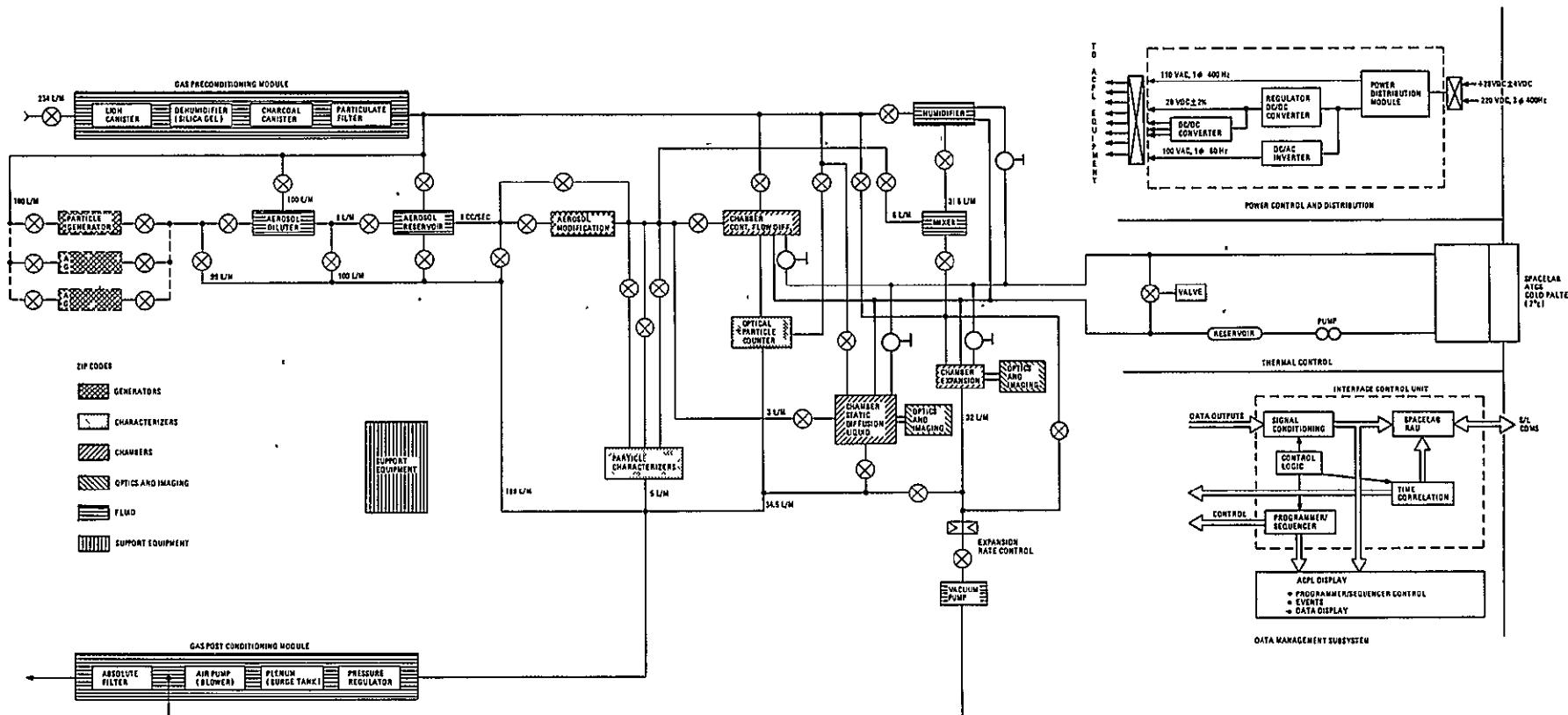


INITIAL ACPL BLOCK DIAGRAM

The block diagram for the Initial ACPL is shown on the facing page. ACPL will use Spacelab atmosphere as the air supply purifying it to experimentation requirements and reconditioning it after experimentation (to requirements specified for Spacelab) prior to reinjection into the cabin. Major operational capability features are shown by the placement of the scientific equipment and the multiple flow paths provided to accommodate anticipated experiment operations. The scientific equipment and flight support subsystem interfaces, internal to the ACPL, are identified. It should be noted that only flight support subsystems (those flown on all missions) interface with Spacelab.



INITIAL ACPL BLOCK DIAGRAM



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PRELIMINARY EVOLUTIONARY GROWTH CONCEPT

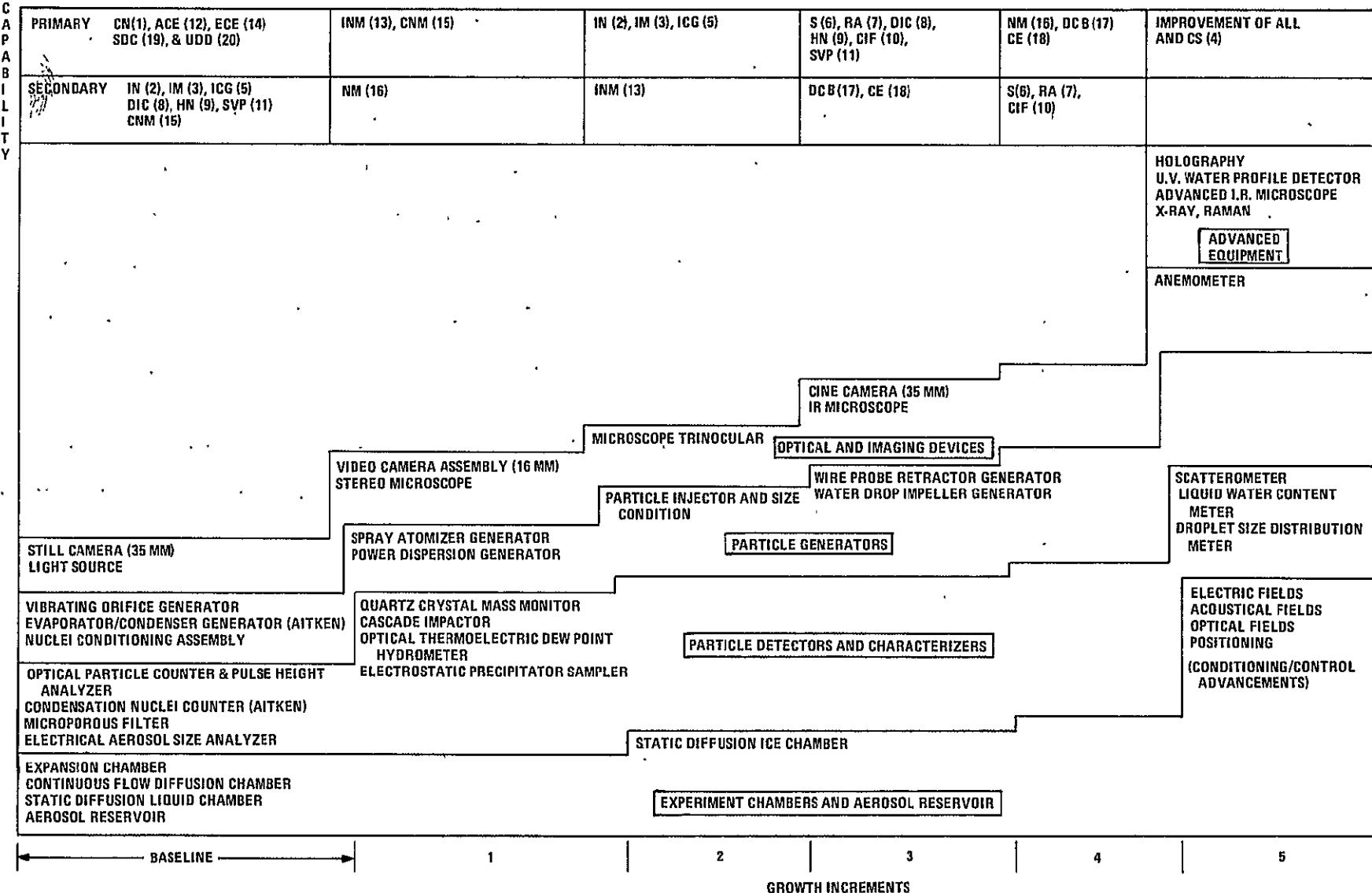
The evolutionary growth concept established as a "point-of-departure" for the ACPL Study is shown on the facing page. This concept identifies five major growth steps in the evolutionary growth process to a Full Capability ACPL. The equipment identified for each growth increment are for scientific equipment subsystems only. In actuality, both the baseline Initial ACPL and the evolutionary growth steps will be modified by the scientific functional requirements and the programmatic constraints. The format shown provides a concise representation of options available for incorporating growth.



PRELIMINARY EVOLUTIONARY GROWTH CONCEPT

EXPLANATION

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EVOLUTIONARY GROWTH ACPL CONCEPT CONFIGURATION

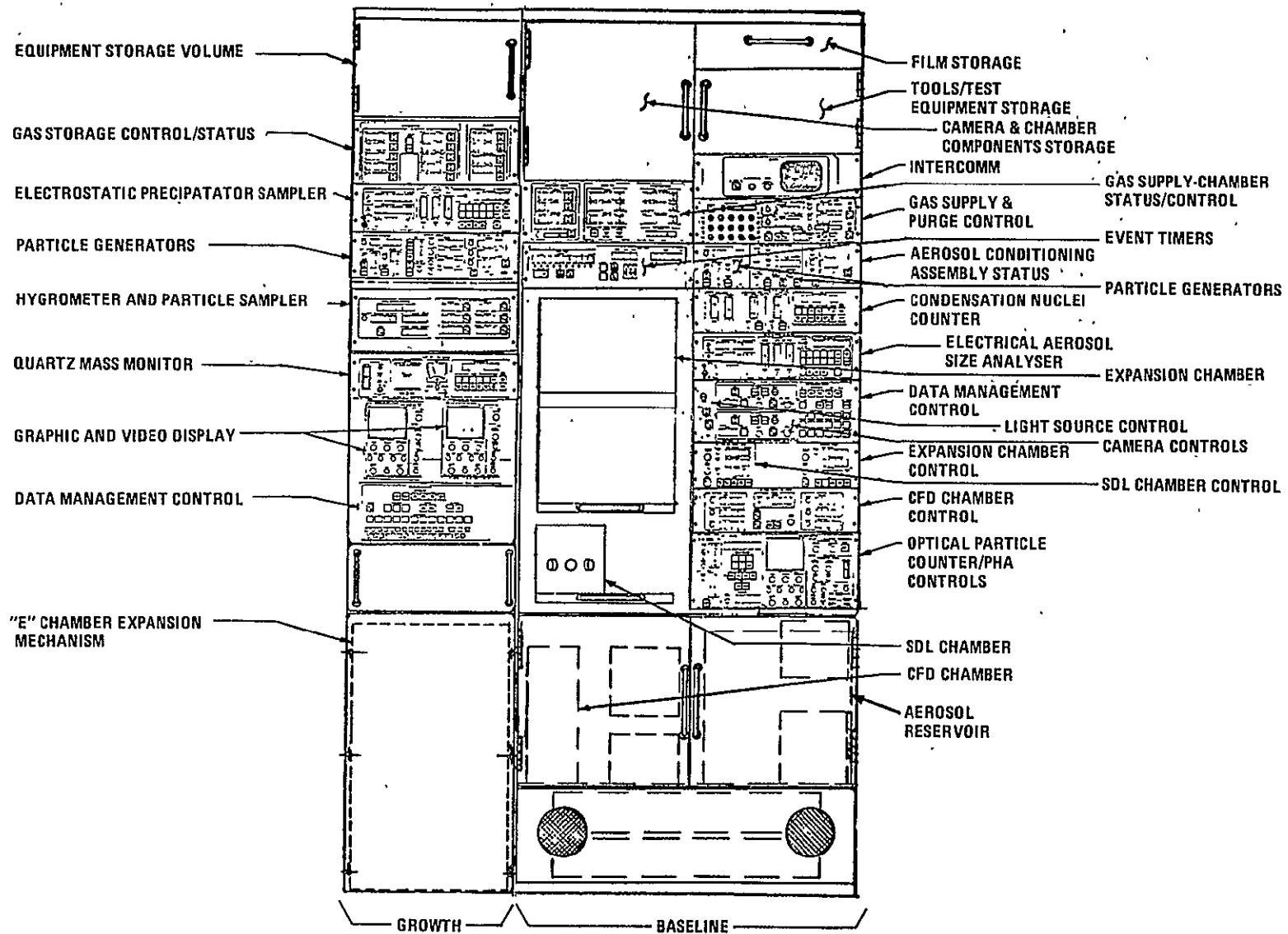
The example shown represents a concept of a full capability ACPL. This example demonstrates that with addition of a single rack, significant additional equipment can be accommodated. The example shown contains three cloud chambers (E, CFD and SDL), additional generators and particle characterizers, expanded graphic and video display, data management control equipment, expansion chamber recompression equipment; trace gas storage bottles and additional equipment storage volume for optics and imaging devices. Although the concept is not representative of a defined experiment it does provide assurance that a Full Capability ACPL can be accommodated in the Spacelab core module and can contain an equipment complement sufficient to perform advanced experiments on long-duration Spacelab missions.

The Full Capability ACPL will use three standard Spacelab racks. The specific complement of scientific equipment subsystems will vary for each flight/mission as required by the specific experiment objectives. The flight support subsystems, however, will be designed to be flown on all missions and to accommodate the maximum requirements imposed by the scientific equipment.



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TYPLICAL EVOLUTIONARY GROWTH ACPL CONCEPT CONFIGURATION



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BASELINE INITIAL ACPL EXPERIMENT SCOPE

The broad experiment capability of the Initial ACPL concept is shown on the facing page. The concept is fully responsive to the warm cloud experimentation processes and provides restricted capability for some cold cloud experimentation processes utilizing the continuous flow diffusion, expansion, and static diffusion liquid cloud chambers. The anticipated restriction on cold cloud experimentation processes is based on the Spacelab cold plate and power capability. Excessive ACPL requirements on these resources would necessitate incorporation of ACPL capability (at increased cost) or restricted Spacelab missions and/or on-orbit experimentation durations.



BASELINE INITIAL ACPL EXPERIMENT SCOPE

EXPERIMENT CLASS NO.	EXPERIMENT CLASS TITLE	DESIGNATION
1	CONDENSATION NUCLEATION	CN
* 2	ICE NUCLEATION	IN
* 3	ICE MULTIPLICATION	IM
* 5	ICE CRYSTAL GROWTH HABITS	ICG
* 8	DROPLET ICE CLOUD INTERACTIONS	DIC
* 9	HOMOGENEOUS NUCLEATION	HN
*11	SATURATION VAPOR PRESSURE	SVP
12	ADIABATIC CLOUD EXPANSION	ACE
14	TERRESTRIAL EXPANSION CHAMBER EVALUATION	ECE
*15	CONDENSATION NUCLEI MEMORY	CNM
19	STATIC DIFFUSION CHAMBER EVALUATION	SDC
20	UNVENTILATED DROPLET DIFFUSION COEFFICIENTS	UDD

*SECONDARY CAPABILITY – RESTRICTED PORTIONS

MISSION/FLIGHT FLEXIBILITY

The Initial ACPL concept mission/flight flexibility is primarily achieved by the modular subsystems/equipment. The flight support subsystems are permanently installed and fly on every mission. The scientific equipment mix, however, will vary dependent upon the specific experiment objectives. Their modular design will enhance reconfiguration and thereby permit a fast response to mission opportunities. Additionally, evolutionally growth equipment can be flight tested since only internal ACPL interfaces exist.



MISSION/FLIGHT FLEXIBILITY

- MODULAR SUBSYSTEMS/EQUIPMENT,
- MISSION EQUIPMENT MIX VARIATION
- SIMPLIFIED RECONFIGURATION
- QUICK RESPONSE TO MISSION OPPORTUNITIES
- FLIGHT TEST OF EVOLUTIONARY GROWTH EQUIPMENT

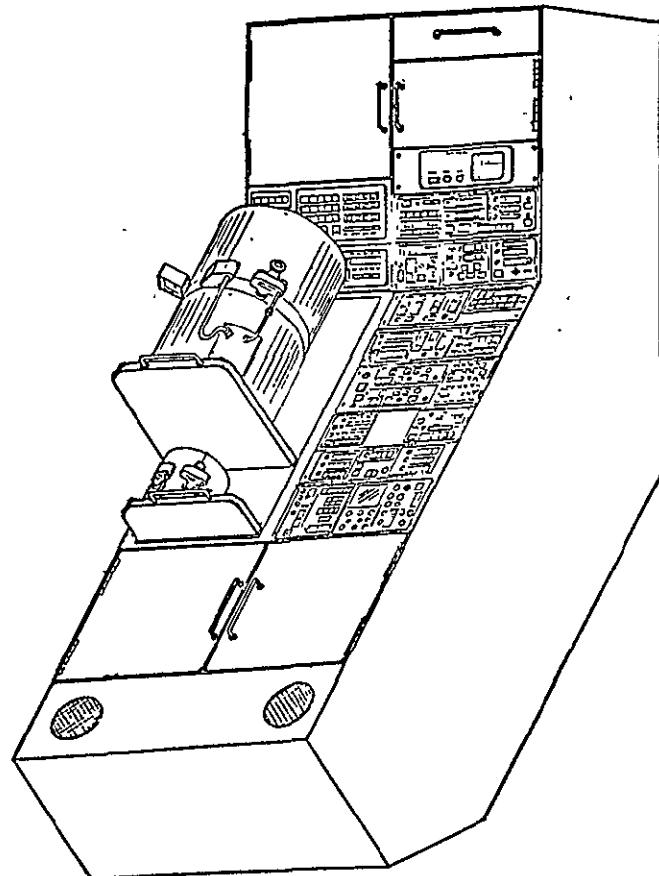
MODULARITY/COMMONALITY

The modularity of the Initial ACPL is provided by common flight support subsystems and modular scientific equipment subsystem elements. This modularity results in discrete front panel elements for the ACPL with the inherent capability for ease of reconfiguration, refurbishment, maintenance and checkout.



MODULARITY/COMMONALITY

- MODULARITY



- STANDARD PANELS
3 SIZES
3 WIDTHS
- STANDARD STORAGE COMPARTMENTS
- RACK STANDARDIZED POWER DISTRIBUTION

- COMMONALITY

- S/L INTERFACES
- THERMAL AND FLUID CONTROL
- DATA MANAGEMENT
- POWER CONDITIONING
- SUPPORT EQUIPMENT
- CPL SUBSYSTEM INTERFACES*
- CLOUD CHAMBERS AND HUMIDIFIER
THERMAL CONTROL SURFACES
- ZERO G – ONE G COMPATABILITY*

*DESIGN GOAL

LOW COST APPROACHES

The advent of reuseable payloads using the Shuttle/Spacelab represents a significant departure from prior NASA programs. Recognition of the influence of cost on the ACPL program prompted emphasis in this area. The facing page identified areas of significant ACPL cost savings. Some of these savings are predicated on a departure from requirements imposed on the prior manned spacecraft programs and, therefore, require approval of NASA.



LOW COST APPROACHES

- PROTOFLIGHT CONCEPT
 - REDUCED RECURRING COST
- S/L CAPABILITY UTILIZATION
 - MINIMIZE ACPL D&D AND RECURRING COST
- EVOLUTIONARY GROWTH CONCEPT
 - REDUCTION/ELIMINATION OF "DEAD-ENDED" EQUIPMENT
 - TECHNOLOGY "CARRY-OVER" FOR LATER MISSIONS
- SUPPORTATIVE LOW COST AREAS
 - COST AVOIDANCE APPROACHES
 - FLIGHT/MISSION FLEXIBILITY
 - MODULARITY/COMMONALITY

SECTION 3
STUDY PLAN

STUDY PLAN OVERVIEW

The Study Plan for the ACPL has been formulated based on the Shuttle/Spacelab usage and the MSFC Industry Briefing of May 1975. The study consists of the eight major tasks previously identified that produce the data requirements required to proceed to ACPL development and production. The manpower for the ACPL consists of the direct contractual effort and the application of significant General Electric discretionary resources. Specific task descriptions are supplied for each study tasks with specific delineation of the task elements (subtasks), the schedule/performance review/data requirements interrelationships and the task approach methodology.

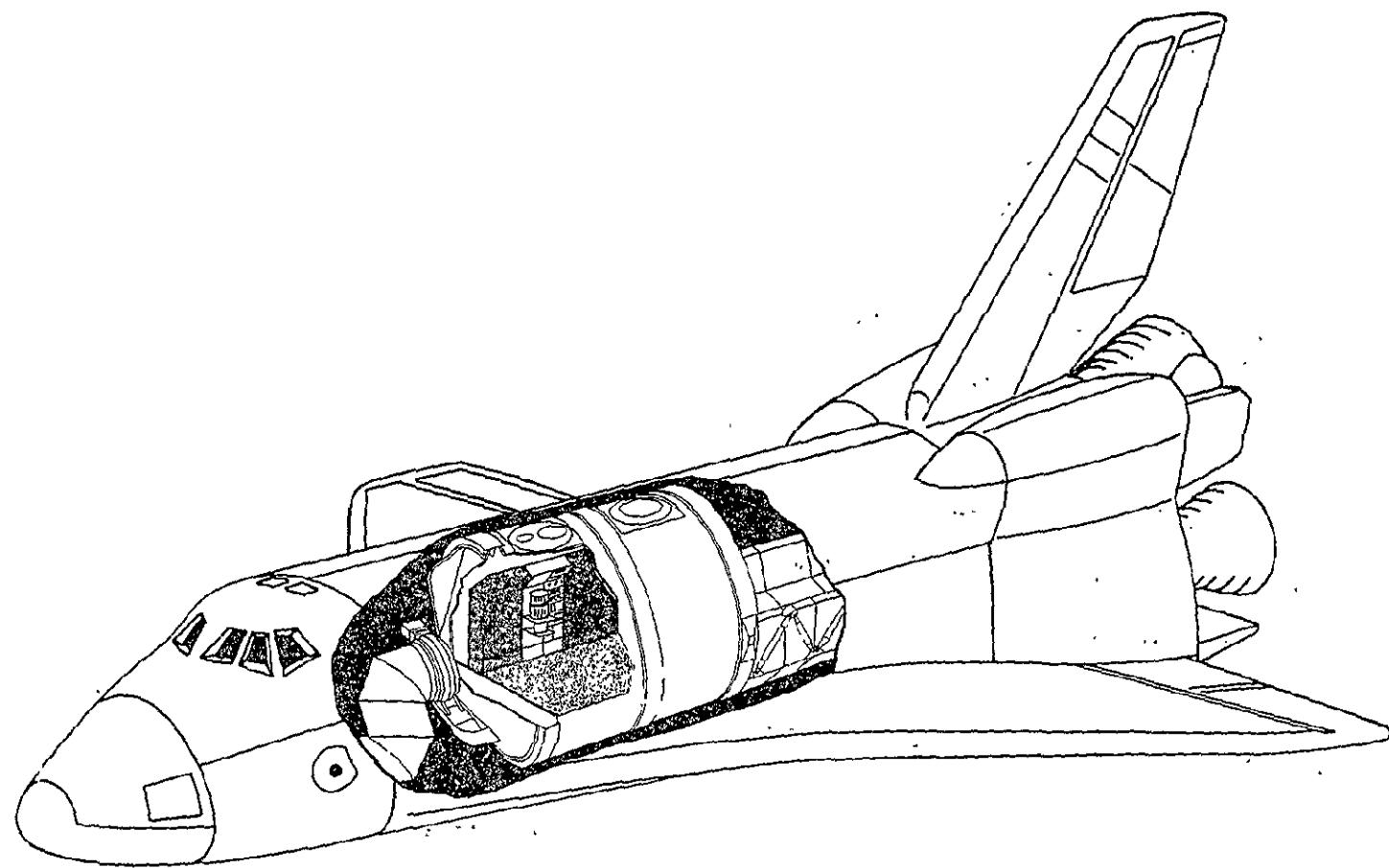


STUDY PLAN OVERVIEW

- **ACPL USAGE**
- **STUDY SUMMARY FLOW**
- **STUDY MANPOWER**
- **TASK DESCRIPTIONS**
 - **TASK ELEMENTS**
 - **SCHEDULE/PERFORMANCE REVIEW/DATA REQUIREMENTS INTERRELATIONSHIP**
 - **TASK APPROACH AND OUTPUTS**

SHUTTLE/SPACELAB

The Shuttle/Spacelab provides a unique opportunity for the performance of cloud microphysics research in a near zero gravity environment. The absence of gravity permits the accomplishment of experiments difficult or impossible to accomplish in a terrestrial laboratory by the extension of experiment observation time. The envisioned ACPL program consists of an Initial ACPL comprised of equipment that can be contained in two standard Spacelab racks and capable of performing significant early research. With evolutionary growth the ACPL will include additional advanced cloud chambers and scientific instruments/equipment capable of performing the broad based experiment program, identified by the prior ACPL studies.



The ACPL study consists of eight major tasks as described in the RFP Statement of Work. The relationship of these tasks to each other and to the study performance reviews is shown in the study summary flow. Study documentation and key features of the performance reviews are included

Task 1 develops scientific functional requirements for the initial and evolutionary cloud physics research program, determines requirements for flight and ground support equipment, and identifies requirements for Supporting Research and Technology (SR&T).

Task 2 addresses two major areas: mission and operations analysis, and systems engineering analysis.

Task 3 analyzes scientific equipment and support subsystems and produces preliminary design drawings and specifications for these items.

Task 4 compiles the results of requirements definition, analyses, and trade studies into Part 1 CEI specifications and functional, physical and procedural ICDs.

Task 5 accomplishes preliminary design of the ACPL, using proposal developed Design Reference Models (DRM's) for the initial ACPL and for evolutionary growth to the full capability ACPL.

Task 6 provides a Work Breakdown Structure and dictionary for use in planning the Phase C/D ACPL program and collecting program costs.

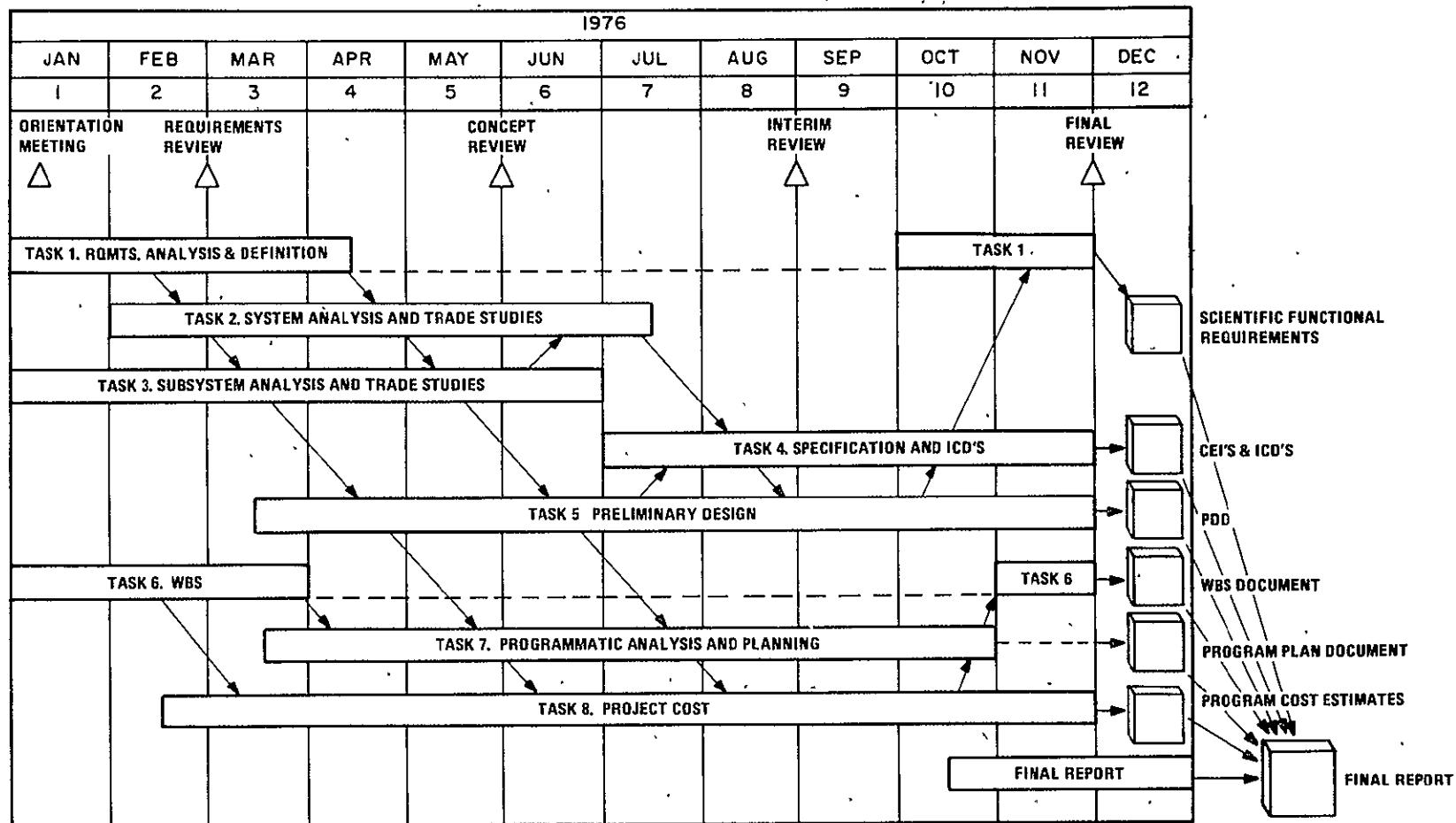
Task 7 integrates the independent task efforts and supplements them by overall ACPL programmatic analyses and planning for each element of the Phase C/D WBS.

Task 8 develops total project costs for the ACPL, with appropriate cost data to WBS level 5.



ACPL STUDY SUMMARY FLOW

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STUDY DIRECT MANPOWER ALLOCATION

The direct manpower/breakout at the task and subtask level are shown on the facing chart. Allocation of the entire 6,795 manhours for the study is shown. These direct study manhours are supplemented by discretionary resources committed to technologies directly applicable to ACPL, other related company efforts, program management, and indirect support provided by the institutional base at Valley Forge. The planned manpower for the study, therefore, is actually 13,486 manhours.



STUDY DIRECT MANPOWER ALLOCATIONS

1976

TASK	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL TOTAL
	1	2	3	4	5	6	7	8	9	10	11	12	
1.1	77	40	26	15	10	8							176
1.2		22	98	48									168
1.3			60	36						14	30		140
2.1	60	44											104
2.2		75	80	90	78	90	77						490
2.3		47	51	58	50	57	62						325
3.1	180	173											353
3.2			109	138	116								363
3.3			117	116	130								363
3.4					109	130							239
4.1							98	100	103	110	91		502
4.2							98	100	103	110	91		502
5.1			50	105	90	95	117	120	115	195	104		991
5.2			11	30	25	30	64	70	85	90	78		483
6.1	41	16	8									10	75
6.2	47	20	8									15	90
7.1			13	18	21								52
7.2			8	20	21	24	22						95
7.3					15	15	16	16					62
7.4									40	49			89
8.1		15	20	25	15								75
8.2			16	15	14	20	15						80
8.3					16	21	15	15					66
8.4						24	20	28	40		44		156
FINAL REPORT											219	537	756

TASK 1 REQUIREMENTS ANALYSES AND DEFINITION

Scientific Functional Requirements

The contractor shall expand and update the scientific functional requirements furnished by NASA to include subsequent requirements as identified, and to distinguish between those requirements which pertain to initial ACPL flight capabilities and those which are identified as a later growth item. The scientific functional requirements shall be documented according to DR-SE-04.

Flight and Ground Support Equipment Requirements Definition

The contractor shall determine the requirements for flight support equipment in sufficient depth to support the preliminary payload definition and systems and subsystems tasks.

The contractor shall determine the requirements for all ground support equipment of the ACPL.

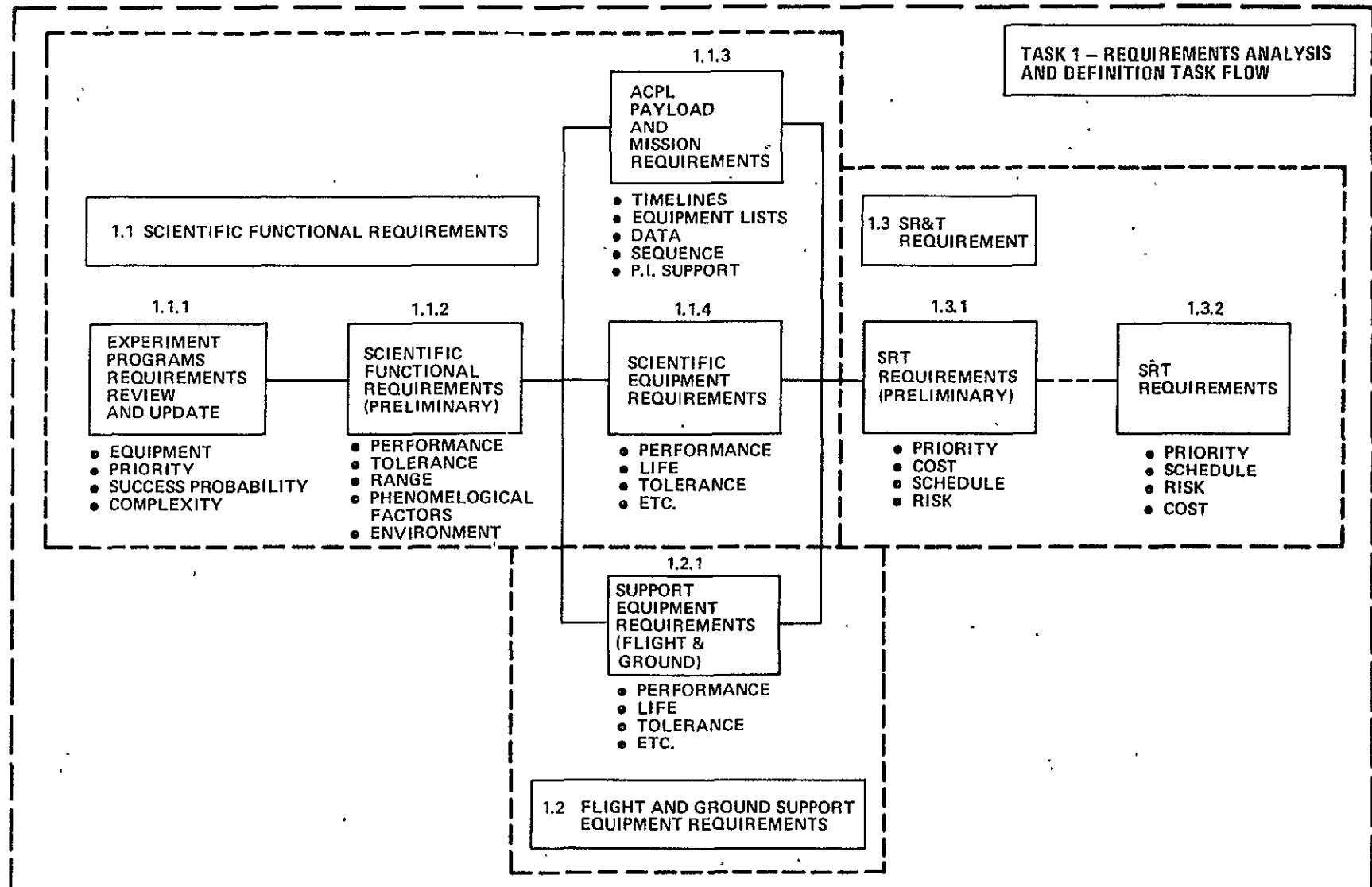
SR&T Requirements

The contractor shall identify required SR&T for initial ACPL flight development as well as growth ideas and submit these in accordance with DR-SE-243B.

SR&T shall be identified and time-phased according to (1) SR&T necessary to be accomplished in order for the recommended initial flight design to be workable and (2) that desirable which will enhance the recommended initial flight design and growth version but not constitute a driver or design need for ACPL to be built relative to state-of-art as currently identified.



TASK 1 REQUIREMENT ANALYSIS AND DEFINITION TASK FLOW



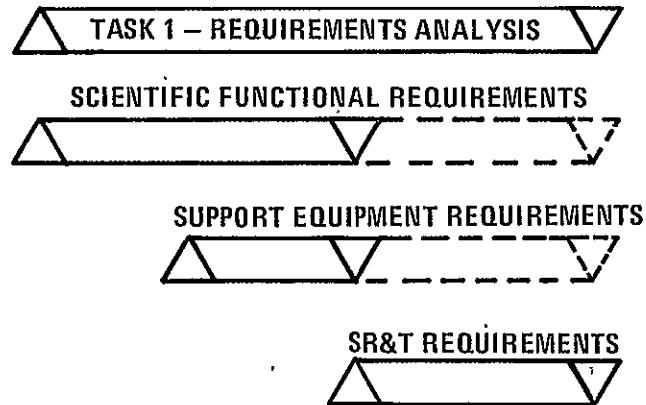
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TASK 1 - REQUIREMENTS ANALYSIS AND DEFINITION

This effort will be conducted in accordance with the task and subtask schedule shown. The relationship of these efforts to the Performance Review requirements are identified.

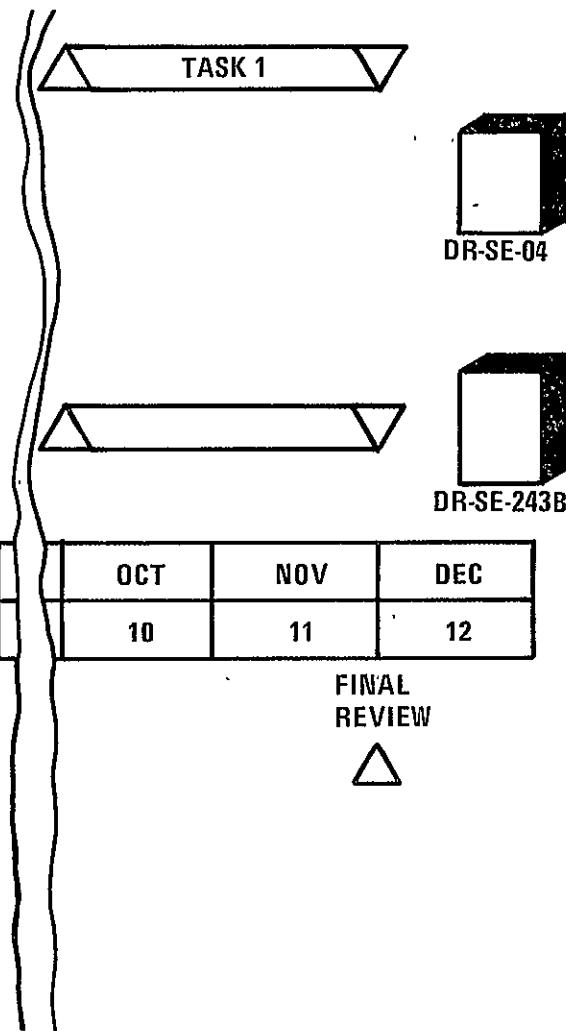


TASK 1 REQUIREMENTS ANALYSES AND DEFINITION



JAN	FEB	MAR	APR	MAY	JUNE	OCT	NOV	DEC
1	2	3	4	5	6	10	11	12

ORIENTATION MEETING <ul style="list-style-type: none"> • STUDY PLAN • GROUND RULES AND GUIDELINES • PERFORMANCE REQUIREMENTS 	REQUIREMENTS REVIEW <ul style="list-style-type: none"> • SCIENCE REQUIREMENTS (PRELIMINARY) • FLIGHT & GROUND SUPPORT EQUIPMENT REQUIREMENTS (PRELIM) • MISSION/PAYLOAD REQUIREMENTS (PRELIM) 	CONCEPT REVIEW <ul style="list-style-type: none"> • SCIENCE EQUIPMENT REQUIREMENTS
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TASK 1 - REQUIREMENTS ANALYSIS AND DEFINITION

Task Objective

Performance of this task results in the detail identification of: a) Scientific (Equipment) Functional Requirements documented in accordance with DR-SE-04, b) Flight and Ground Support Equipment Requirements documented in accordance with DR-SE-04, and c) Supporting Research and Technology (SR&T) Requirements documented in accordance with DR-SE-243B. These requirements will be formulated for the Initial ACPL and identified for ACPL growth.

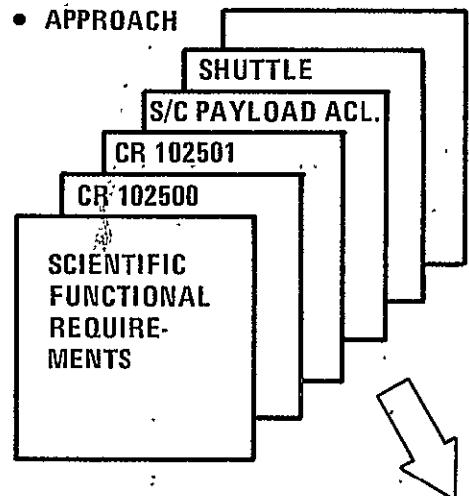
Technical Approach

Requirements definition for the ACPL is a key factor to study success. The task technical approach is formulated to assure the adequacy and accuracy of requirements defined. The approach incorporates test and evaluation of scientific equipment and the use of scientific consultants and cloud microphysics instrument manufacturers to support the definition of scientific (equipment) functional requirements. These requirements, in turn, provide the basis for formulation of requirements for the ACPL flight support equipment and ground support equipment. The requirements for Shuttle/Spacelab and manrating are superimposed on the basic requirements. The scientific (equipment) functional requirements also form the basis for the technology evaluation of ACPL SR&T. Initial SR&T definitions are further evaluated in the system, subsystem and preliminary design tasks (Tasks 2, 3, and 5 respectively) and finalized at the completion of the study.



TASK 1 REQUIREMENTS ANALYSES AND DEFINITION

- APPROACH



- OUTPUT

DR-SE-04

COMPONENT/SUBSYSTEM REQUIREMENTS

- PURPOSE
- DESCRIPTION/FUNCTION
- PERFORMANCE



- DATA
- ELECTRICAL
- ENVIRONMENTAL
- STRUCTURAL/MECHANICAL

DR-SE-243B

- EQUIPMENT
- STATUS
- JUSTIFICATION
- TECHNICAL PLAN
- RESOURCES
- SCHEDULE

SCIENTIFIC EQUIPMENT SUBSYSTEMS

- CHAMBERS/RESERVOIR
- GENERATORS
- CHARACTERIZERS
- OPTICS/IMAGING

FLIGHT SUPPORT SUBSYSTEMS

- DATA MANAGEMENT
- POWER CONDITIONING
- THERMAL/FLUID CONTROL SUPPORT EQUIPMENT

INITIAL
ACPL
FUNCTIONAL
REQMTS.

GROWTH
ACPL
FUNCTIONAL
REQMTS.

SR&T
REQMTS.

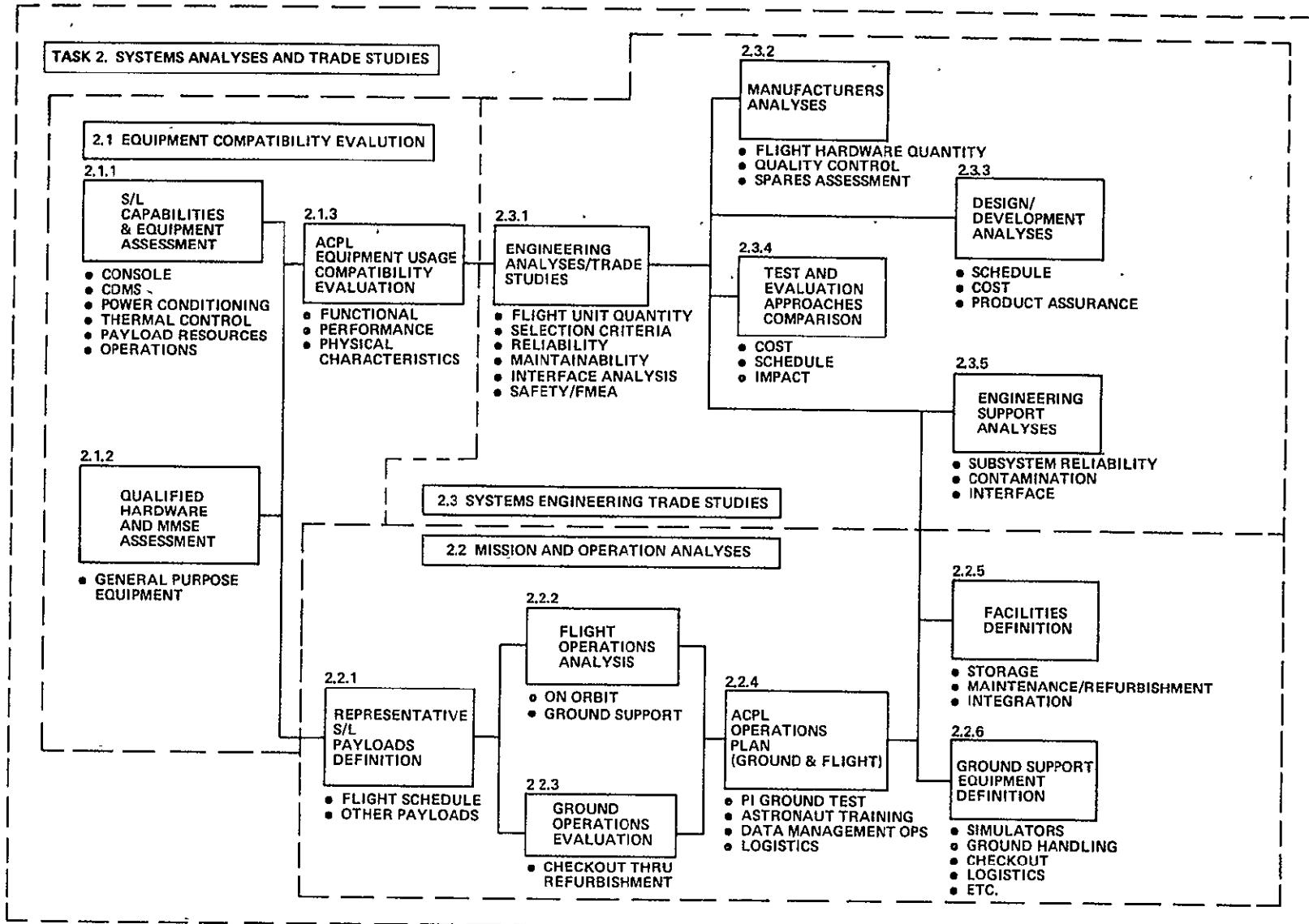
TASK 2 SYSTEMS ANALYSES AND TRADE STUDIES

The contractor shall accomplish all necessary system engineering and analyses, system level trade studies, sensitivity analyses, interface analyses, mission and operation analyses, testing analyses, safety analyses, maintenance analyses, contamination analyses, hazard analyses, failure mode effects analyses, cost analyses and cost trades in support of the preliminary design for the development of the lowest possible cost ACPI program consistent with required technical performance and hardware delivery schedule. The contractor shall conduct these efforts such that the various system approaches can be analyzed and, to the maximum practical extent, alternatives eliminated prior to in-depth design. Results of this task shall be documented in accordance with DR-MA-04.



TASK 2

SYSTEM ANALYSES AND TRADE STUDIES TASK FLOW



TASK 2 - SYSTEM ANALYSES AND TRADE STUDIES

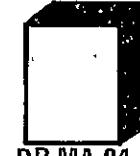
This effort will be conducted in accordance with the task and subtask schedule shown. The relationship of these efforts to the Performance Review requirements are identified.



TASK 2 SYSTEMS ANALYSES AND TRADE STUDIES

TASK 2 SYSTEM ANALYSES/TRADE STUDIES

EQUIPMENT COMPATABILITY

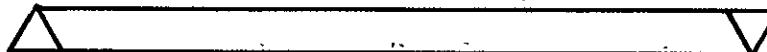


MISSION/OPS ANALYSIS



DR-MA-04

SYSTEM ENGR TRADES



JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2	3	4	5	6	7	8	9

ORIENTATION
MEETING



REQUIREMENTS
REVIEW



CONCEPT
REVIEW



INTERIM
REVIEW



- FLIGHT & GROUND SUPPORT EQUIPMENT CONCEPT
- SYS/SUBSYS ANALYSIS & TRADES

- INTERIM DESIGN OF FLT & GROUND SUPPORT EQPT FOR INITIAL FLIGHTS

TASK 2 - SYSTEMS ANALYSES AND TRADE STUDIES

Task Objective

This task is performed in support of the ACPL preliminary design. Analysis and trade studies will be conducted to establish the lowest possible cost ACPL program consistent with required technical performance and schedule objectives. This task will result in definition of system engineering approaches, the ACPL Ground and Flight Operations Plan and the associated facilities and ground support equipment in accordance with DR-MA-04 definitions.

Technical Approach

The systems analysis and trade studies provide the primary supportive efforts for the ACPL preliminary design (Task 5) and suboptimized/supportive efforts for programmatic planning (Task 7). The task technical approach consists of two major effort areas: a) Systems Engineering Trade Studies, and b) Mission and Operations Analysis. These major efforts are supported by the Equipment Compatibility Evaluation effort. This approach permits the various system level alternatives to be analyzed and evaluated for conformance to ACPL capability, program schedule and programmatic cost objectives.



TASK 2 SYSTEMS ANALYSES AND TRADE STUDIES

- APPROACH – MINIMIZE ACPL PROGRAM COST

SYSTEMS ENGINEERING TRADE STUDIES

MODEL	A	B	C	D	E	F	G	H	J	K	L	M	N	O
REQUIREMENT	DT	QT	MU	SS	STV	DVH	TM	PVM	FM	PPV	IVU	SIM	PROD	S
COMPONENT/ASSEMBLY DEVELOPMENT	*	*						*						
COMPONENT/ASSEMBLY QUALIFICATION			*											
COMPONENT/ASSEMBLY INTEGRATION AND SUBSYSTEM DEVELOPMENT														
SYSTEM INTEGRATION AND SYSTEM DEVELOPMENT														
SYSTEM VERIFICATION (QUALIFICATION)														
SYSTEM ACCEPTANCE TEST														*
SYSTEM TESTS														
INTERVAL TESTS														
MISSILE DEVR TOOL FAB														
INTERFACE VERIFICATION WITH SPACELAB								*						
GHQ SYS CBL AND PROG INT														
PAYOUTLOAD INTEGRATION														
TRAINING / MISSION PLANNING														
OPERATIONAL POINT														
TURNOVER/DECOMMISSION														
FLIGHT TESTING														
LAUNCH BACK UP														
END DESIGN SUPPORT	*	*	*					*						
PROPELLANT TESTING														
EXPERIMENT INTEG (PII)														
DT = DEVELOPMENT TEST														
QT = QUALIFICATION TEST														
MU = SUBSYSTEM MODELS (I.E. BENCH MODELS)														
SS = STRUCTURE TEST VEHICLE														
STV = DYNAMIC TEST UNIT														
DVH = DYNAMIC VERIFICATION														
TM = THERMAL MODEL														
PTV = PROJECT VERIFICATION MODEL														
PPV = PROJECT PROTOTYPING VEHICLE														
IVU = INTERFACE VERIFICATION UNIT														
SIM = SIMULATOR														
PROD = PROTOTYPING (FLIGHT ARTICLE)														
S = SPARES SUPPORT OR TESTING														

MISSION AND OPERATIONS ANALYSES

- GROUND
- FLIGHT
- PAYLOAD SPECIALIST
- PRINCIPAL INVESTIGATOR
- SHUTTLE/SPACELAB CONSTRAINTS
- FACILITIES

EQUIPMENT COMPATABILITY EVALUATION

- SHUTTLE
- SPACELAB
- MMSE
- SPACE QUALIFIED HARDWARE

- OUTPUT

DR-MA-04

- PROGRAM MANAGEMENT
- ✓ • SYSTEMS ENGINEERING AND INTEGRATION
- ✓ • DESIGN AND DEVELOPMENT
- ✓ • SYSTEMS TEST
- GSE DESIGN AND DEVELOPMENT
- ✓ • MANUFACTURING
- ✓ • PRODUCT ASSURANCE
- ✓ • FACILITIES
- ✓ • GROUND OPERATIONS
- ✓ • MISSION OPERATIONS

- ✓ • PARTIAL INPUT

TASK 3 SUBSYSTEM ANALYSES AND TRADE STUDIES

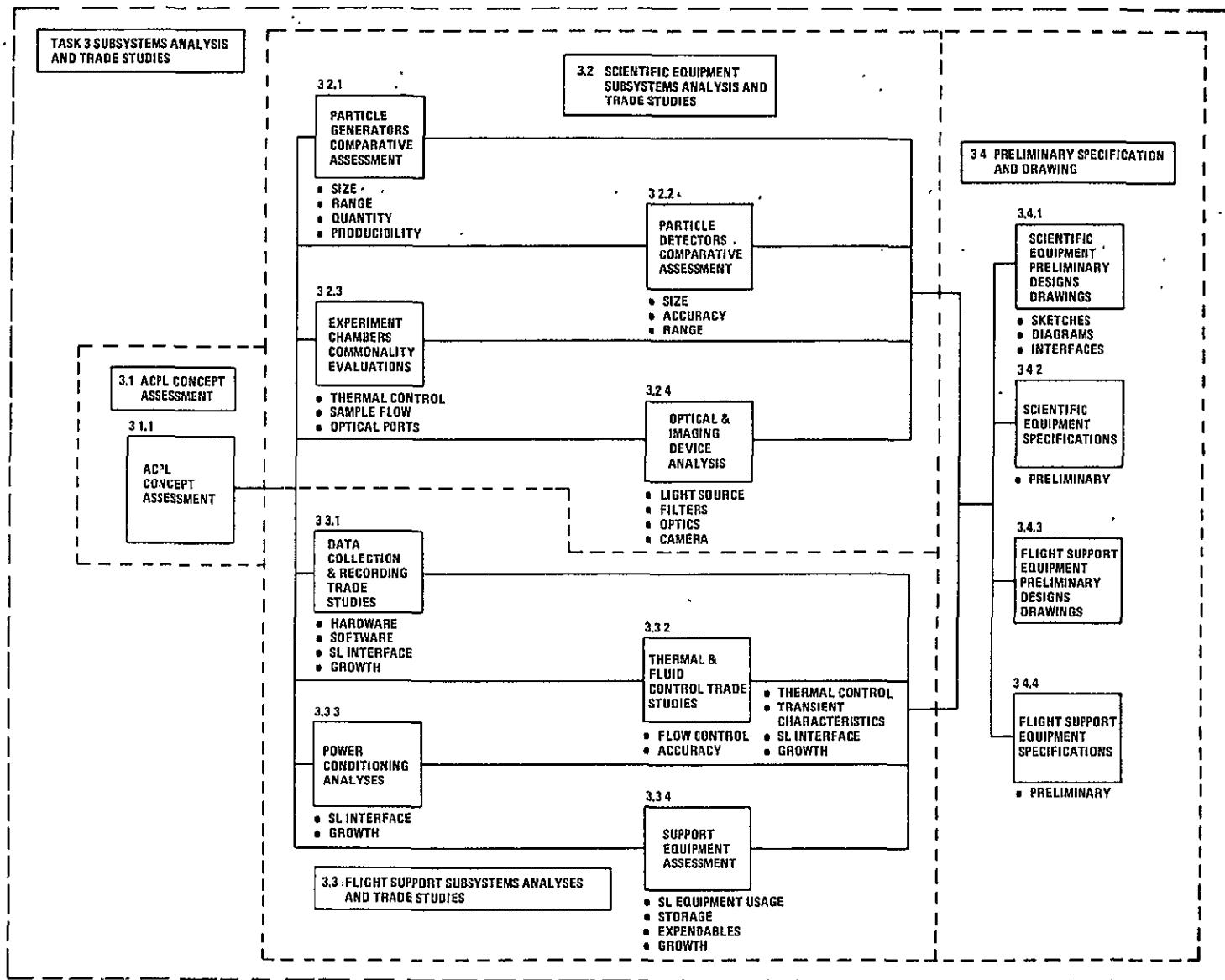
The contractor shall conduct subsystems analyses and trade studies in support of Task 2 and shall produce subsystem preliminary designs, including drawings and specifications, which satisfy requirements identified through Task 1 and 2. Subsystem designs shall comply with all applicable system requirements such as productibility, maintainability, reliability, safety, electromagnetic compatibility, testability, and modularity.

Results of Task 3 shall be documented in accordance with DR-MA-03, DR-MA-04, DR-MA-05, and DR-SE-01, and DR-SE-02, and DR-SE-03.



TASK 3 SUBSYSTEM ANALYSES AND TRADE STUDIES TASK FLOW

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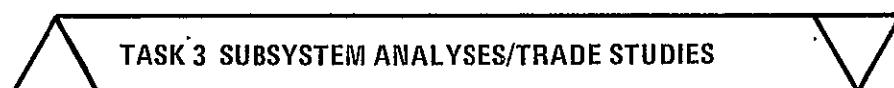
TASK 3 - SUBSYSTEM ANALYSES AND TRADE STUDIES

This effort will be conducted in accordance with the task and subtask schedule shown. The relationship of these efforts to the Performance Review requirements are identified.



SPACE
DIVISION

TASK 3
SUBSYSTEM ANALYSES AND TRADE STUDIES



CONCEPT ASSESSMENT

SCIENTIFIC S/S ANALYSES

FLT SUPPORT S/S ANALYSES

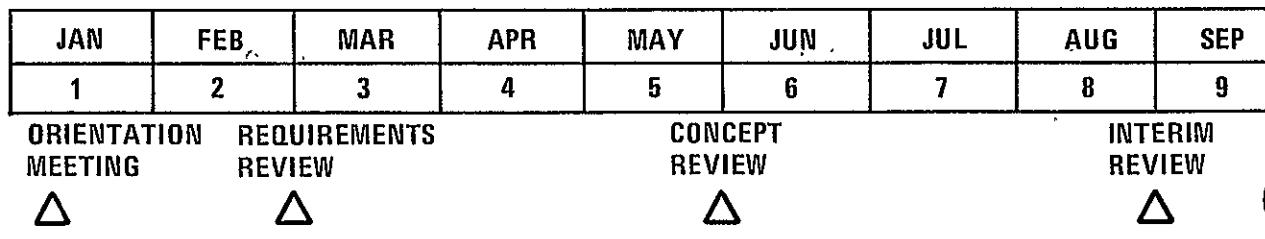
PRELIM SPECS/DWGS



DR-MA-04



DR-SE-01/2/3



- SYS/SUBSYS ANALYSIS & TRADES

- PRELIM CEI'S & ICD'S ON HARDWARE FOR INITIAL FLIGHTS

TASK 3 - SUBSYSTEMS ANALYSES AND TRADE STUDIES

Task Objective

The performance of this task produces the subsystem preliminary designs including drawings and specifications in conformance with the requirements generated under Task 1 and Task 2. Results of this task will produce the specified data for the work statement identified documentation.

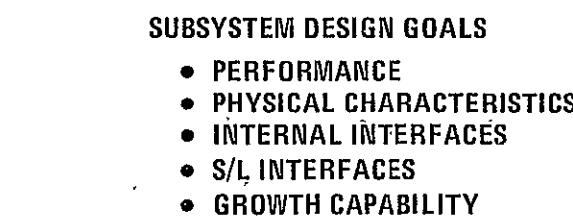
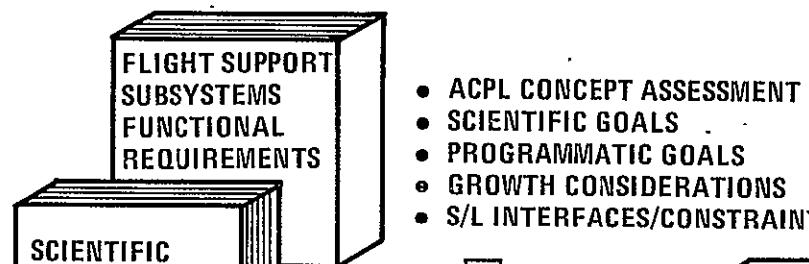
Task Approach

The Initial ACPL Baseline Preliminary Design and the Evolutionary Growth Model, as updated at the Study Orientation Meeting will provide a point of departure for this task. Subsystems identified in the Work Breakdown Structure will be categorized into the previously identified groups of Scientific Equipment Subsystems and Flight Support Subsystems. This task performs independent assessments of the ACPL subsystems and prepares the required drawings, specifications and documentation. In addition to the trade studies and analyses identified in the study logic, test and evaluation of specific Scientific Equipment will be performed to aid in the establishment of the selected equipment design concepts. Primary emphasis will be placed on the equipment identified for the Initial ACPL.



TASK 3 SUBSYSTEM ANALYSES AND TRADE STUDIES

- APPROACH

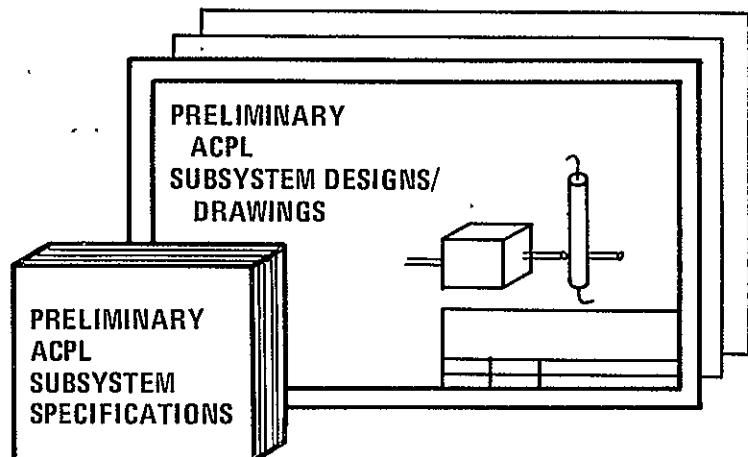


- CRITERIA

SCIENTIFIC RESPONSIVITY
PROGRAMMATIC COST AND SCHEDULE
TECHNOLOGY STATUS
SPACELAB CAPABILITIES
OPERATIONS GUIDELINES/CONSTRAINTS

- OUTPUT
- PRELIMINARY DRAWINGS MIL-STD-1000
- PRELIMINARY SPECIFICATIONS MM 8040.12
- DATA REQUIREMENT INPUTS
- DR-MA-03
- DR-MA-04
- DR-MA-05
- DR-SE-01
- DR-SE-02
- DR-SE-03

- SUBSYSTEM CONCEPT COMPARISONS
- CHARACTERISTICS TRADEOFFS
- REQUIREMENTS COMMONALITY EVALUATION
- TECHNOLOGY ASSESSMENT
- TEST DATA



TASK 4 - SPECIFICATIONS AND INTERFACE CONTROL DOCUMENTS (ICD's)

Specifications

The contractor shall prepare preliminary Part I CEI Specifications for all identified flight and ground support equipment, test and checkout equipment, and facilities. This specification shall be submitted in accordance with DR-SE-03.

Critical Long Lead Items

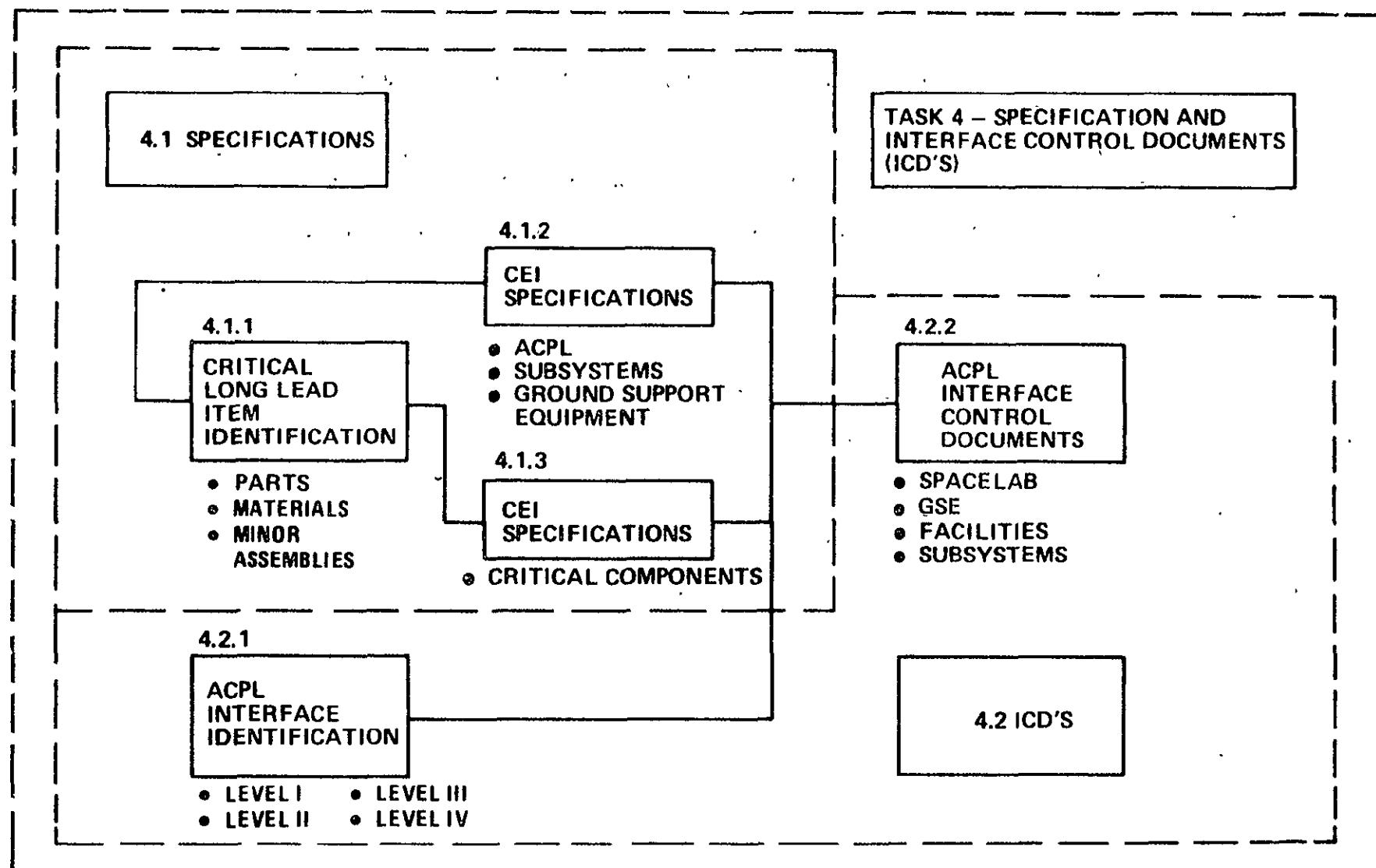
The contractor shall identify and define required long lead procurement items and shall prepare specifications necessary for procurement of these items.

ICD's

The contractor shall prepare preliminary functional, physical and procedural ICD's for all identified interfaces (such as ACPL/Spacelab, GSE/Facilities, GSE/ACPL, etc.). The ICD's shall be submitted in accordance with DR-SE-02.



TASK 4 SPECIFICATIONS AND INTERFACE CONTROL DOCUMENTS TASK FLOW

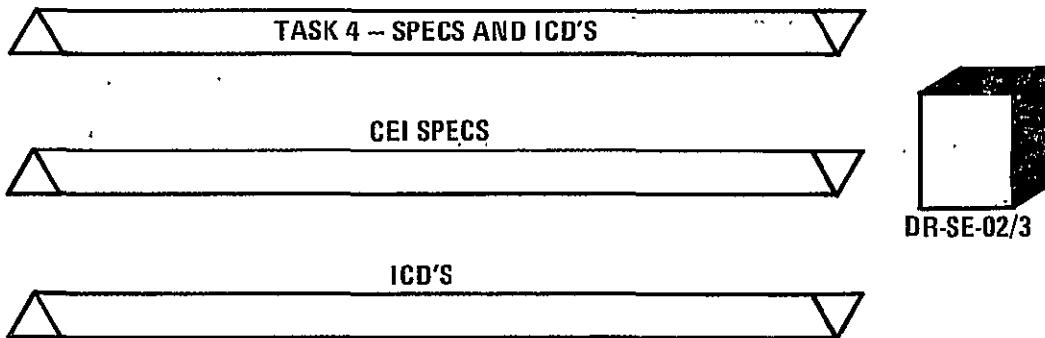


TASK 4 - SPECIFICATIONS AND INTERFACE CONTROL DOCUMENTS

This effort will be conducted in accordance with the task and subtask schedule shown. The relationship of these efforts to the Performance Review requirements are identified.



TASK 4 SPECIFICATIONS AND INTERFACE CONTROL DOCUMENTS



APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
4	5	6	7	8	9	10	11	12

CONCEPT REVIEW 	INTERIM REVIEW 	FINAL REVIEW 
<ul style="list-style-type: none">• IDENTIFICATION OF CRITICAL AREAS/COMPONENTS	<ul style="list-style-type: none">• PRELIM CEI'S & ICD'S ON HARDWARE FOR INITIAL FLIGHTS	<ul style="list-style-type: none">• IDENTIFY LONG LEAD PROCUREMENT ITEMS

TASK 4 - SPECIFICATIONS AND INTERFACE CONTROL DOCUMENTS (ICD's)

Task Objectives

This task will formulate and document: a) Part 1 CEI Specifications for all identified flight and ground support equipment, test and checkout equipment and facilities, b) specifications for all long lead procurement items, and c) preliminary functional, physical and procedural ICD's for all identified interfaces. The Part 1 CEI Specifications and ICD's will be documented in accordance with DR-SE-03 and DR-SE-02 respectively.

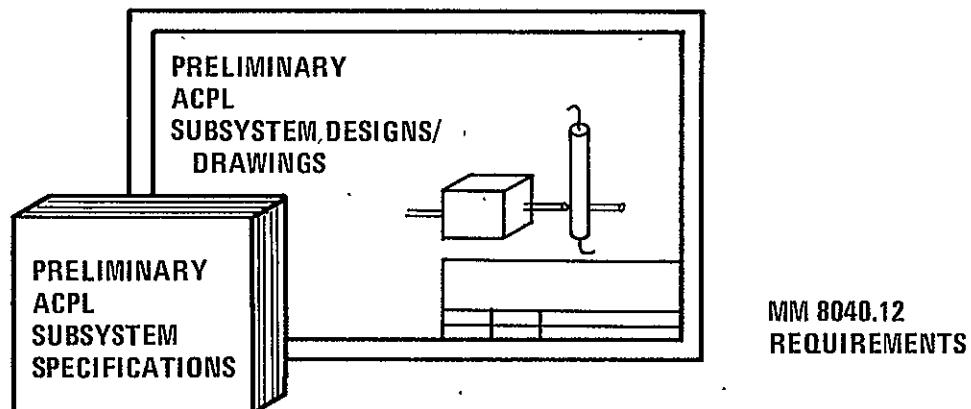
Technical Approach

This task will compile, correlate, integrate and document the results of the requirements definition analyses and trade studies conducted in other areas. The CEI Specifications will be developed as the primary design control document for Phase C/D, and will reflect finalized Phase B study results.



TASK 4 SPECIFICATIONS AND INTERFACE CONTROL DOCUMENTS

- APPROACH



- OUTPUT

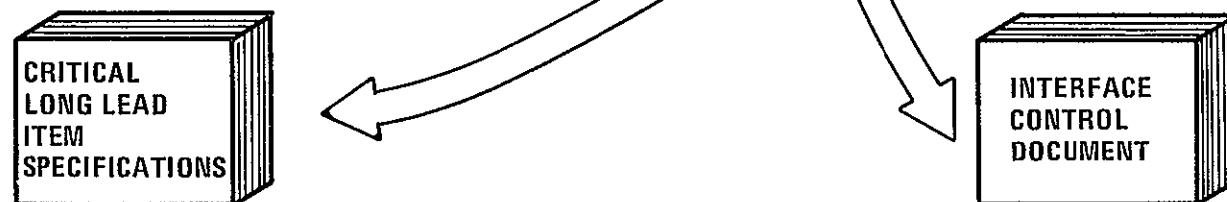
DR-SE-03
CEI PART 1 SPECIFICATIONS

DR-SE-02
ICD'S

- REQUIREMENTS
- INFORMATION SOURCES
- REFERENCE BASELINE

- INTERFACE EVALUATIONS

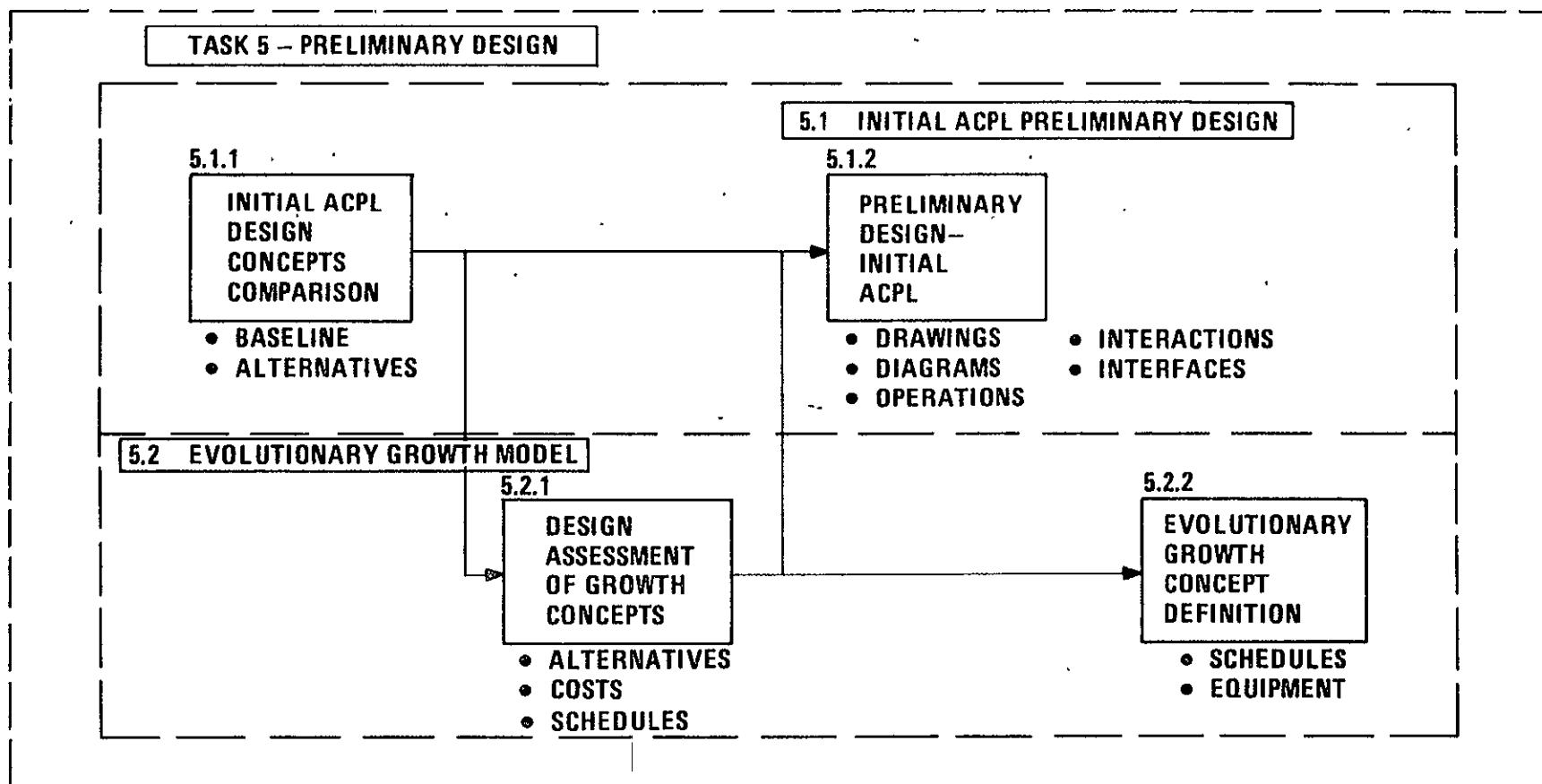
SPACELAB FACILITIES
GSE SUBSYSTEMS



TASK 5 PRELIMINARY DESIGN

The contractor shall accomplish an in-depth preliminary design of an ACPL for the early Spacelab missions. This preliminary design shall reflect the lowest possible program cost consistent with required technical performance and schedules. The preliminary design shall satisfy the ACPL scientific objectives for the initial Spacelab flights. However, consideration shall be given to the evolutionary approach of the ACPL program which calls for major experimentation in cold cloud processes. This task shall be documented per DE-SE-01.

TASK 5 PRELIMINARY DESIGN TASK FLOW

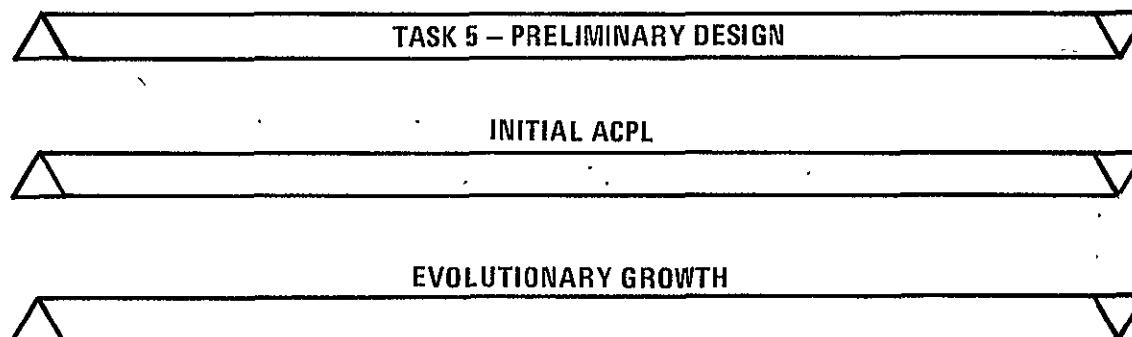


TASK 5 - PRELIMINARY DESIGN

This effort will be conducted in accordance with the task and subtask schedule shown. The relationship of these efforts to the Performance Review requirements are identified.



TASK 5 PRELIMINARY DESIGN



JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	2	3	4	5	6	7	8	9	10	11	12

ORIENTATION
MEETING



REQUIREMENTS
REVIEW



CONCEPT
REVIEW



INTERIM
REVIEW



- INTERIM DESIGN OF LAB FOR INITIAL FLIGHTS

FINAL
REVIEW



- PAYLOAD DEFINITION
- PRELIMINARY DESIGN FOR INITIAL PAYLOAD & SUPPORT EQUIPMENT

TASK 5 - PRELIMINARY DESIGN

Task Objective

This task will accomplish an ACPL preliminary design for the early Spacelab missions, and reflect the lowest possible cost consistent with scientific/technical requirements and schedules. Consideration of evolutionary growth, including cold cloud processes experimentation will be considered. Results of all task efforts shall be documented in accordance with DR-SE-01.

Technical Approach

The preliminary design for the ACPL shall be performed using the Design Reference Model's (DRM's) for the Initial ACPL and for the Evolutionary growth Model to the Full Capability ACPL. The Initial ACPL Baseline will be used to establish concept alternatives to achieve the lowest cost, supportive analyses for human factors, and operational characteristics design analyses. The evolutionary growth concepts design analyses, being performed in parallel with the Initial ACPL concepts, will be assessed. This iterative approach will result in a finalized Initial ACPL preliminary design and an evolutionary growth concept definition.

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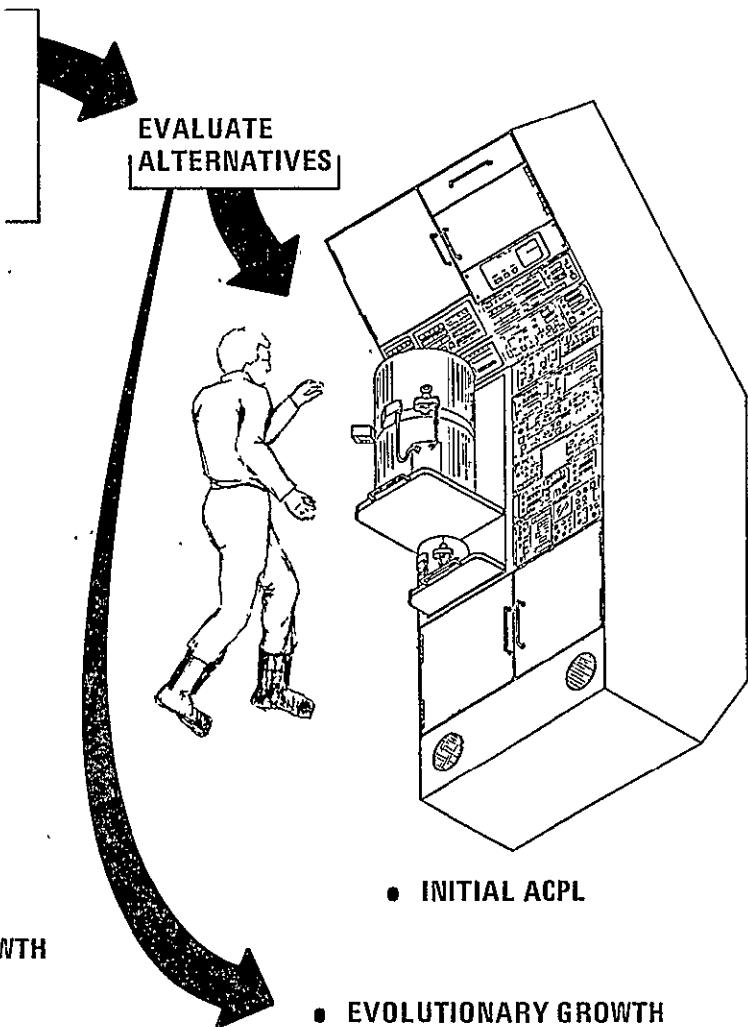
TASK 5 PRELIMINARY DESIGN

- APPROACH

- BASELINE ACPL
- CEI SPECIFICATIONS
- SYSTEM ANALYSES
AND TRADE RESULTS

- CRITERIA

- PERFORMANCE
- COST
- SCHEDULE
- EVOLUTIONARY GROWTH



- OUTPUT

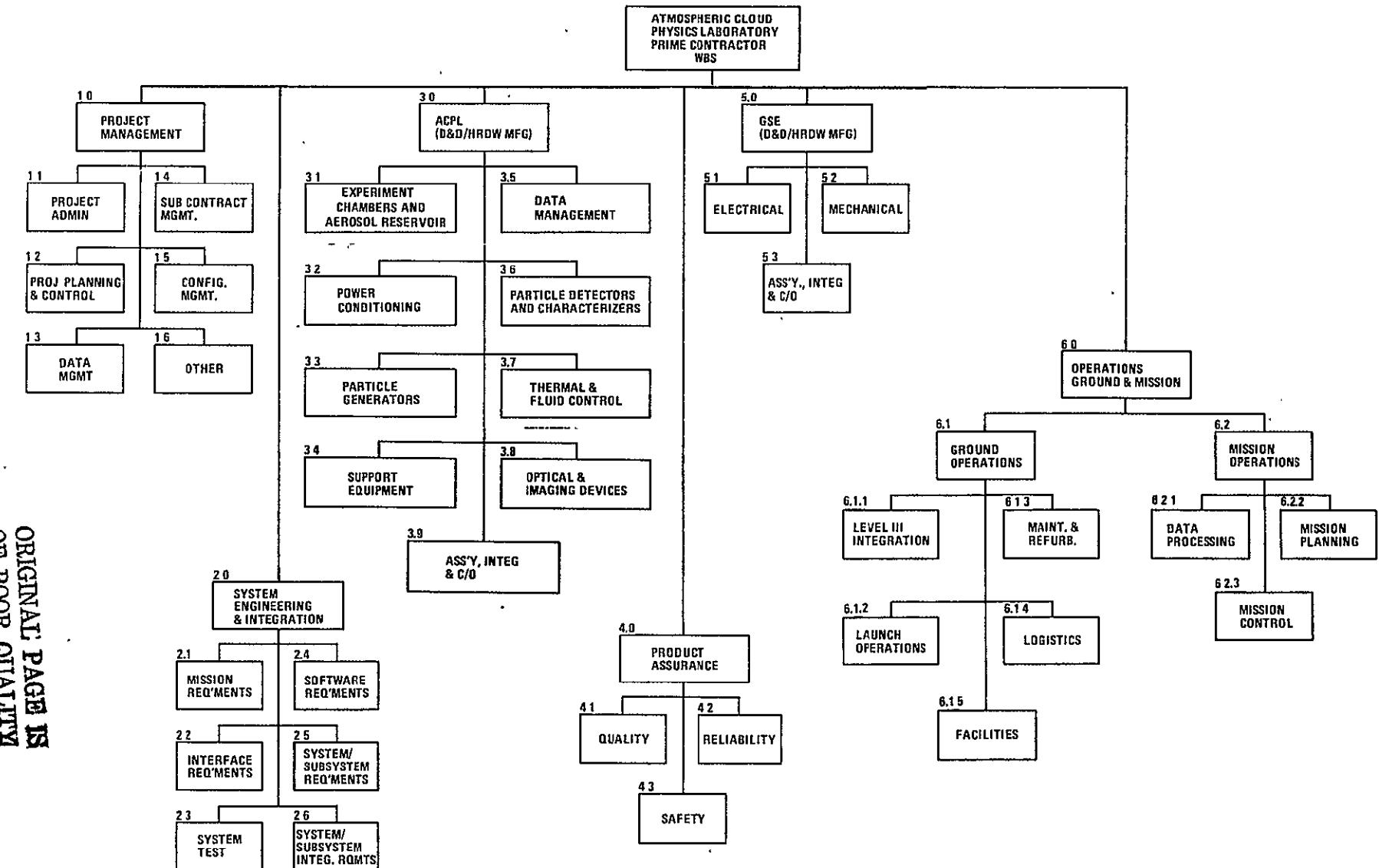
- INITIAL ACPL PRELIMINARY DESIGN
- EVOLUTIONARY GROWTH CONCEPT
- DATA REQUIREMENT INPUTS
- DR-SE-01
- MIL-D-1000

TASK 6 - WORK BREAKDOWN STRUCTURE (WBS) AND DICTIONARY

The WBS, provided as Attachment 2, shall be modified as required by the contractor to display the total activities and work to be performed within the project. WBS Level 5 elements displayed on Attachment 2 are representative only. Modifications shall be discussed with the NASA during the first 30 days of the contract and finalized within 30-60 days after contract award. A preliminary WBS dictionary is required 90 days after contract award. The final WBS dictionary containing updated and final definitions is required at contract completion. All data developed under this task shall be prepared and submitted in accordance with DR-MA-06.



TASK 6 WORK BREAKDOWN STRUCTURE



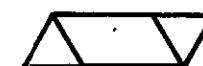
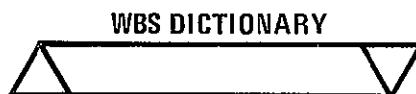
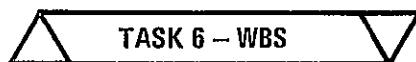
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TASK 6 - WORK BREAKDOWN STRUCTURE

This effort will be conducted in accordance with the task and subtask schedule shown. The relationship of these efforts to the Performance Review requirements are identified.



TASK 6 WORK BREAKDOWN STRUCTURE



DR-MA-06

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	2	3	4	5	6	7	8	9	10	11	12

ORIENTATION
MEETING

REQUIREMENTS
REVIEW

CONCEPT
REVIEW

INTERIM
REVIEW

FINAL
REVIEW



• PRELIM WBS



• WBS

TASK 6 - WORK BREAKDOWN STRUCTURE (WBS) AND DICTIONARY

Task Objective

This task will provide the Work Breakdown Structure (WBS) and Dictionary in accordance with DR-MA-06 requirements. The initial study WBS will be discussed with NASA during the Orientation Meeting and finalized 30-60 days after contract award and the WBS Dictionary will be completed within 90 days. This document will be modified and updated in concurrence with study results and formally submitted at the completion of the study.

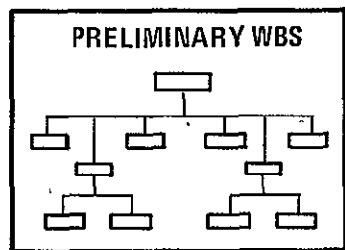
Technical Approach

The General Electric WBS, has been generated with consideration of the RFP Attachment 2 and presents modifications consistent with the proposed Preliminary Baseline Initial ACPL concept. This WBS, updated by General Electric's ACPL project efforts prior to Study ATP, will form the basis of discussion with NASA MSFC personnel at the Orientation Meeting. The results of this meeting and the initial study efforts will result in a preliminary WBS and Dictionary 90 days after ATP. Subsequently this document will be maintained and updated throughout the Study as a fundamental project management tool and finalized and formally submitted, in accordance with the requirements of DR-MA-06 at completion of the Study.



TASK 6 WORK BREAKDOWN STRUCTURE AND DICTIONARY

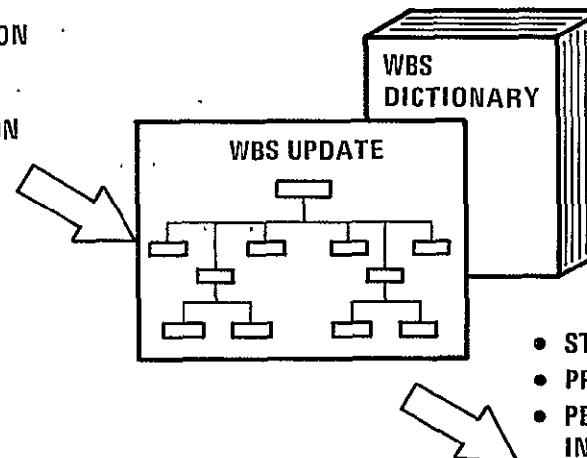
- APPROACH



ORIENTATION
MEETING
CRITIQUE
EVALUATION

- OUTPUTS

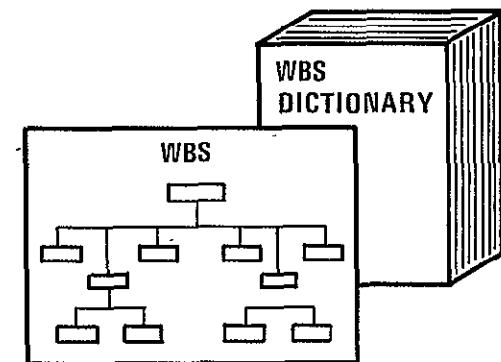
DR-MA-06



- STUDY TASK RESULTS
- PROGRAMMATIC DIRECTION
- PERFORMANCE REVIEW
- INPUTS

WBS USAGE

- PROGRAMMATIC STRUCTURE
 - COST ESTIMATES
 - SCHEDULE DETERMINATION
 - TECHNICAL PLAN DEVELOPMENT
 - SPECIFICATION FORMULATION



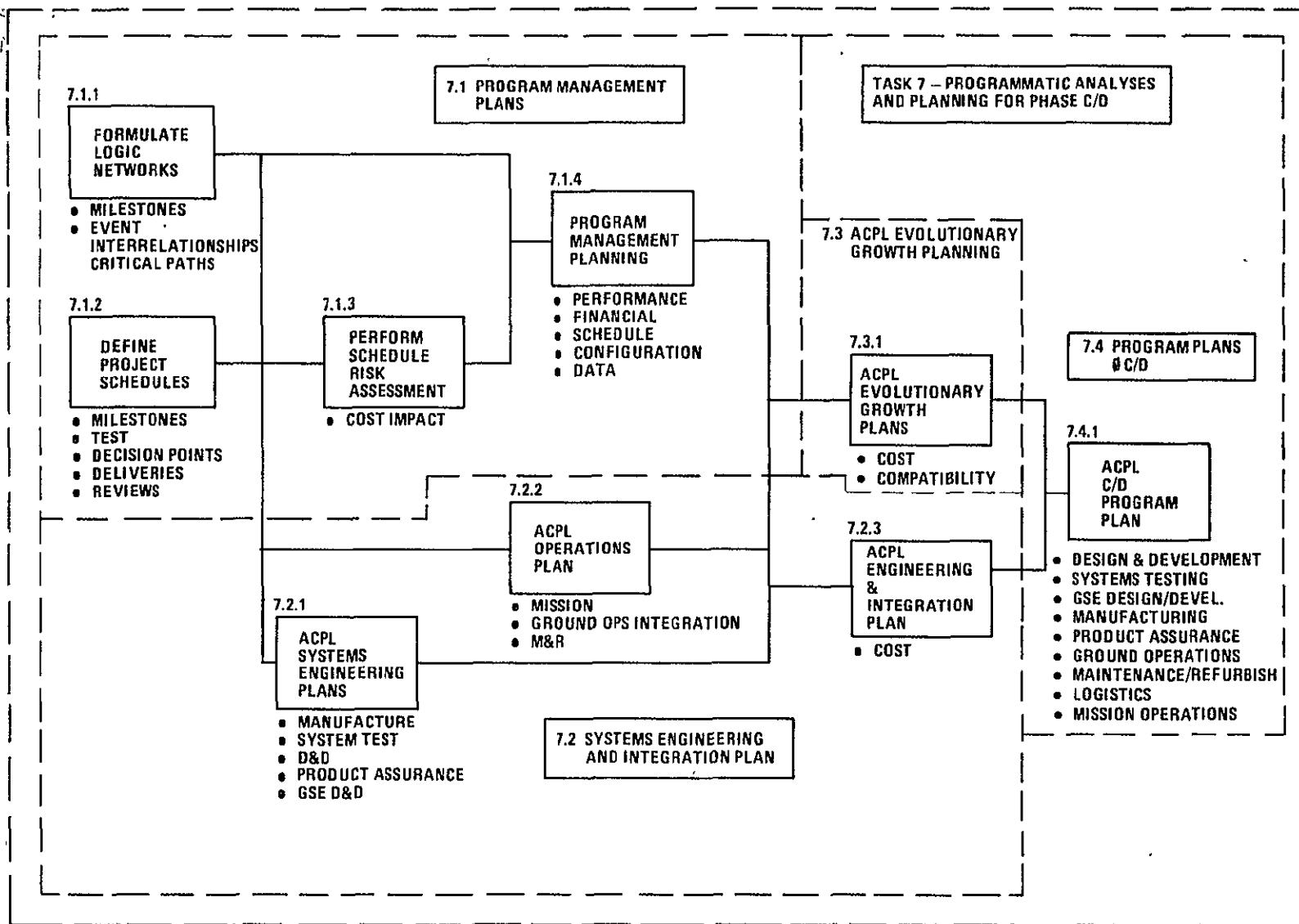
TASK 7 - PROGRAMMATIC ANALYSES AND PLANNING FOR PHASE C/D

The contractor shall accomplish programmatic analyses and planning for each element of the Phase C/D Work Breakdown Structure. These analyses and planning shall be done in sufficient depth to

(a) define and understand the scope and requirements for each WBS element, (b) define the planning necessary to accomplish each WBS element, and (c) ascertain the resources (cost, manpower, facilities) required to accomplish each WBS element. As appropriate, the planning data shall be supported, with requirements/alternatives, analyses, performance/cost trades and sensitivity analyses.

The data generated in this task shall be provided in accordance with DR-MA-04

TASK 7 PROGRAMMATIC ANALYSES AND PLANNING FOR PHASE C/D TASK FLOW



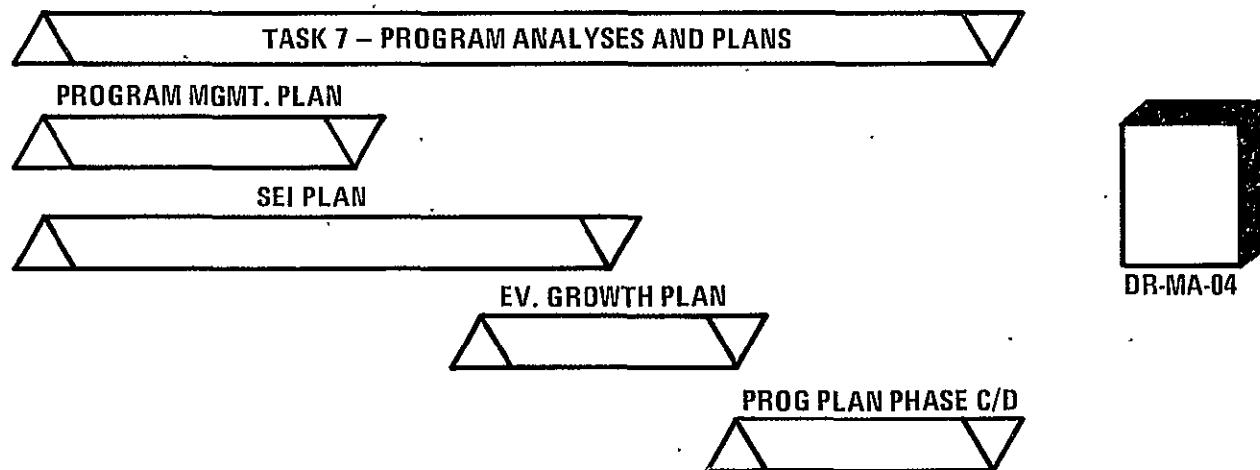
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TASK 7 - PROGRAMMATIC ANALYSES AND PLANNING FOR PHASE C/D

This effort will be conducted in accordance with the task and subtask schedule shown. The relationship of these efforts to the Performance Review requirements are identified.



TASK 7 PROGRAMMATIC ANALYSES AND PLANNING FOR PHASE C/D



JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	2	3	4	5	6	7	8	9	10	11	12

ORIENTATION
MEETING

REQUIREMENTS
REVIEW

CONCEPT
REVIEW

INTERIM
REVIEW

FINAL
REVIEW



- MISSION & PAYLOAD
PLAN (PRELIMINARY)
- OPERATIONS ANALYSIS
(PRELIMINARY)

- OPERATIONS
ANALYSIS (FINAL)
- RISK ANALYSIS

TASK 7 - PROGRAMMATIC ANALYSES AND PLANNING FOR PHASE C/D

Task Objective

The object of this task is to organize, combine, correlate and integrate the independent task efforts, and supplement them by the overall ACPL programmatic analyses and planning for each element of the Phase C/D Work Breakdown Structure. The data produced will be submitted in accordance with DR-MA-04.

Technical Approach

The task flow for this effort was formulated to define the complete approach to the Phase C/D design, development and operational phases of the ACPL Program. The approach identifies the formulation of program management planning and the correlation of the other study efforts into an overall Systems Engineering and Integration (SEI) plan. The interaction of these basic plans for the Initial ACPL with the top level planning, for the evolutionary growth to the Full Capability ACPL, is established prior to finalization of the Phase C/D Program Plan.

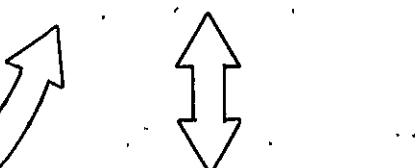
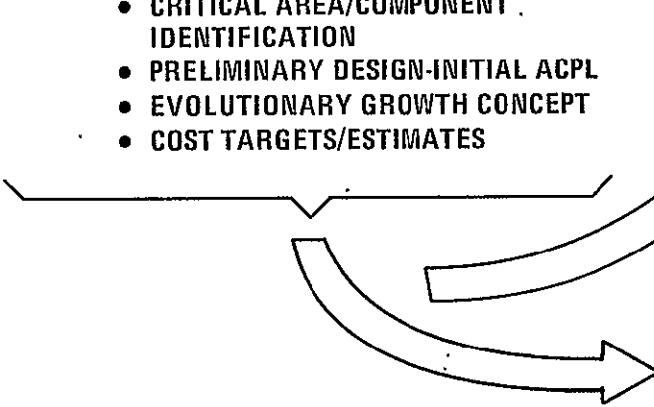
TASK 7

PROGRAMMATIC ANALYSES AND PLANNING FOR PHASE C/D

- APPROACH

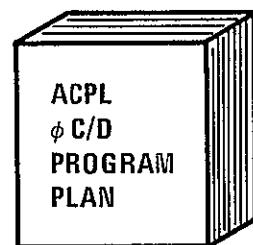
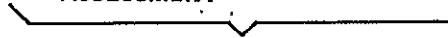
- GROUNDRULES/GUIDELINES
- SYSTEM ANALYSES AND TRADE RESULTS
- SUBSYSTEM ANALYSES AND TRADE RESULTS
- CRITICAL AREA/COMPONENT IDENTIFICATION
- PRELIMINARY DESIGN-INITIAL ACPL
- EVOLUTIONARY GROWTH CONCEPT
- COST TARGETS/ESTIMATES

MILESTONE IDENTIFICATION
SCHEDULE DEFINITION
PROJECT MANAGEMENT PLAN
SCHEDULE RISK ASSESSMENT
COST IMPACT ASSESSMENT
EVOLUTIONARY GROWTH-COST EFFECTIVENESS



SYSTEM ENGINEERING EFFORTS
TEST PHILOSOPHY
PRODUCT ASSURANCE
D&D - FLIGHT SYSTEM
MANUFACTURE
D&D GSE

FLIGHT OPERATIONS ANALYSES
LOGISTICS EVALUATION
MAINTENANCE/REFURBISHMENT
ASSESSMENT



- OUTPUT

DR-MA-04

- PROGRAM MANAGEMENT
- SYSTEMS ENGINEERING AND INTEGRATION
- DESIGN AND DEVELOPMENT
- GSE DESIGN AND DEVELOPMENT
- MANUFACTURING
- PRODUCT ASSURANCE
- FACILITIES
- GROUND OPERATIONS
- MISSION OPERATIONS

TASK 8 - PROJECT COSTS

The contractor shall develop all related Phase C/D project costs required for the ACPL Project and provide detailed cost data with cost definition and discussion at the appropriate WBS level.

The contractor shall also describe in detail the costing methodology used in generating cost estimates.

The cost estimates shall include hardware costs directed toward an evolutionary build-up approach with special emphasis placed on the first Spacelab mission. The costs shall be reported to WBS Level 5 or lower for performance and/or cost critical items. Appropriate consideration shall be given to minimizing early year and peak year funding requirements. Costs subsequent to the first flight (i.e., for the remaining years of operation) shall be developed, appropriately documented, and fully supported by analyses and trades.

During the course of this study, the contractor shall report the cost estimates in accordance with Paragraph 7.3.

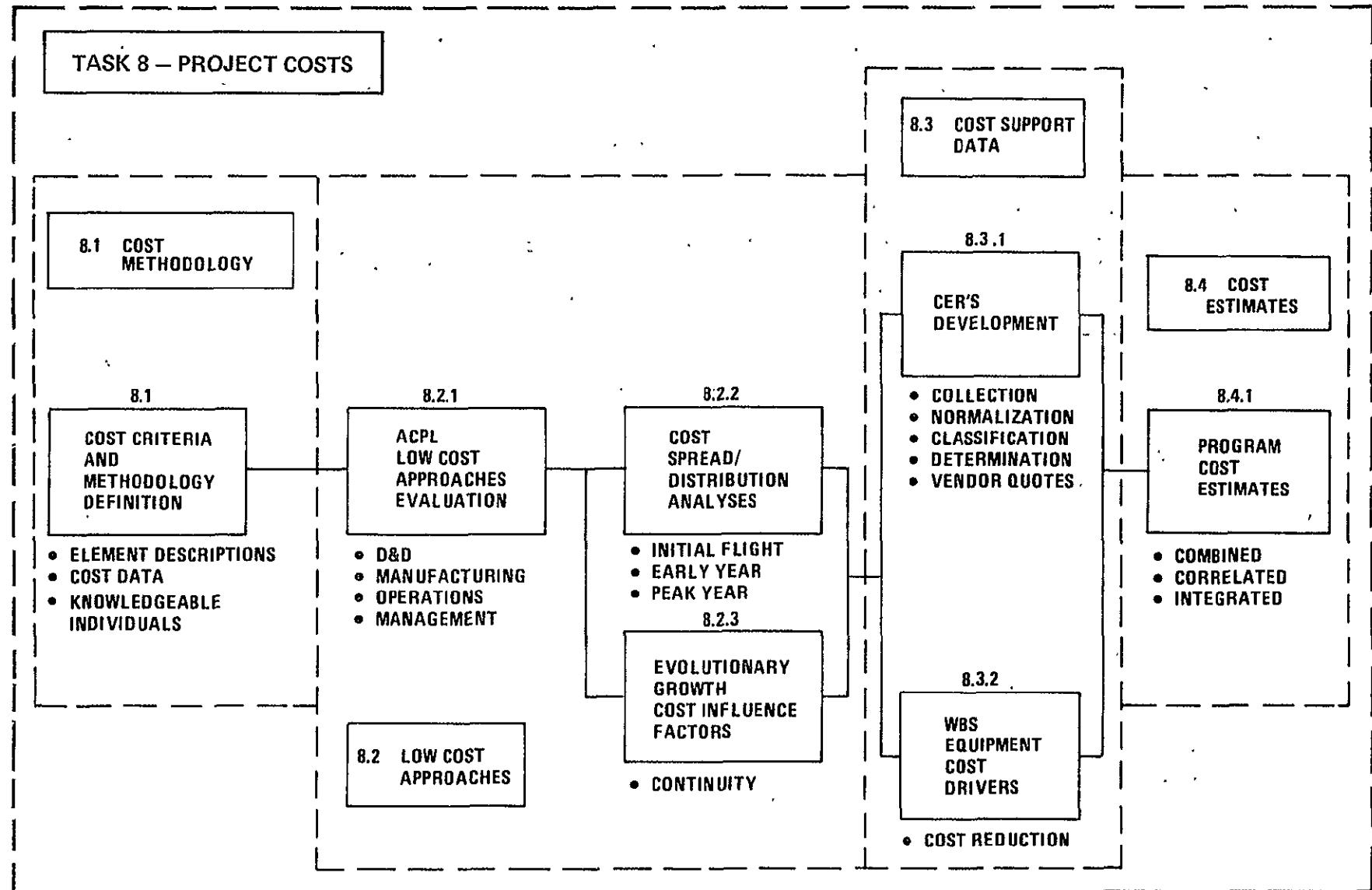
In addition, the contractor shall prepare a master equipment list which will identify applicable off-the-shelf components and subsystems including vendor source and cost estimates.

All data developed and reported under this task shall be prepared and submitted in accordance with DR-MF-003R.



TASK 8 PROJECT COST TASK FLOW

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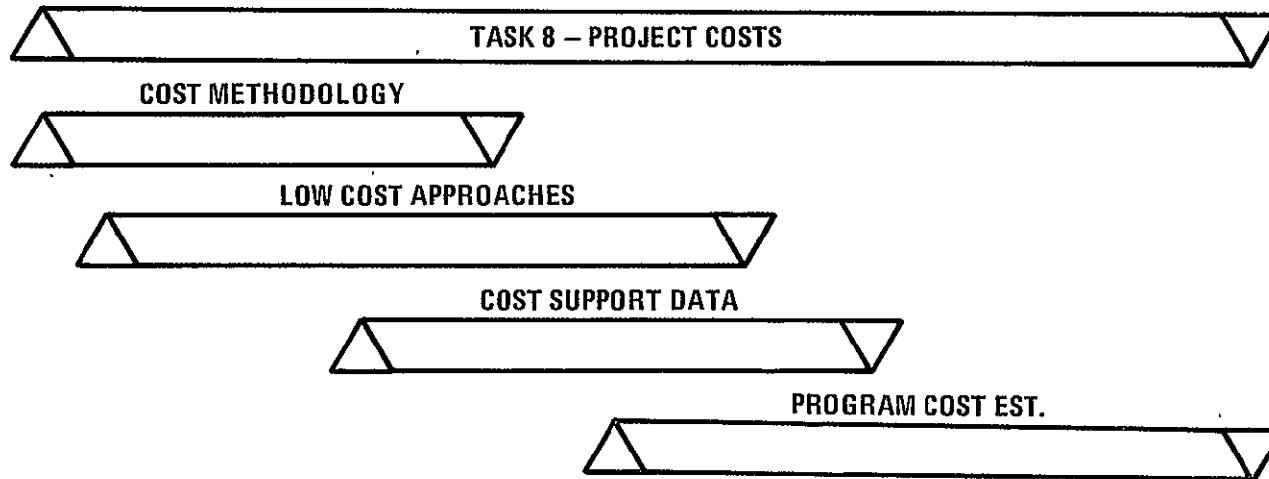


TASK 8 - PROJECT COSTS

This effort will be conducted in accordance with the task and subtask schedule shown. The relationship of these efforts to the Performance Review requirements are identified.



TASK 8 PROJECT COSTS



JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	2	3	4	5	6	7	8	9	10	11	12

ORIENTATION
MEETING



REQUIREMENTS
REVIEW



- COST TARGETS

CONCEPT
REVIEW



- PERFORMANCE/COST
ESTIMATES (PRELIM.)

INTERIM
REVIEW



- INTERIM COST
ESTIMATE

FINAL
REVIEW



- COST ESTIMATES
(FINAL)
- RISK ANALYSIS

TASK 8 - PROJECT COSTS

Task Objective

The total project costs for the ACPL, with appropriate detailed cost data to WBS level 5, will be developed by this task. These costs will be supported by the definition of the methodology used in formulating the estimates. Special emphasis is to be directed to the first Spacelab mission. The ACPL master equipment list, identifying applicable off-the-shelf equipment, sources and cost estimates will be defined. All data from this task will be submitted in accordance with DR-MR-003R.

Technical Approach

Cost estimates for the ACPL will be prepared using the General Electric cost methodology evolved during more than 20 years of aerospace programs and projects. These cost estimates will be formulated based on tradeoffs and analyses conducted to identify low-cost and cost effective management, design and development engineering, manufacturing and operational approaches. The results of the cost analyses performed under the other study tasks will be utilized to substantiate and justify the total project cost. The analyses to minimize early year and peak year funding will be performed in accordance with the RFP guidelines for use of constant 1976 dollars, costs at WBS level 5 or lower, and the exclusion of user charges, Spacelab hardware costs and Principal Investigator costs.

TASK 8 PROJECT COSTS

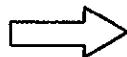
- APPROACH

GE COST METHODOLOGY
ACPL EQUIPMENT DATA BASE
COST ESTIMATING RELATIONSHIPS
INSTRUMENT MANUFACTURER EXPERIENCE

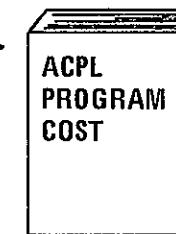
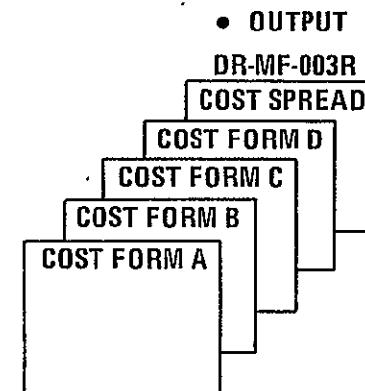
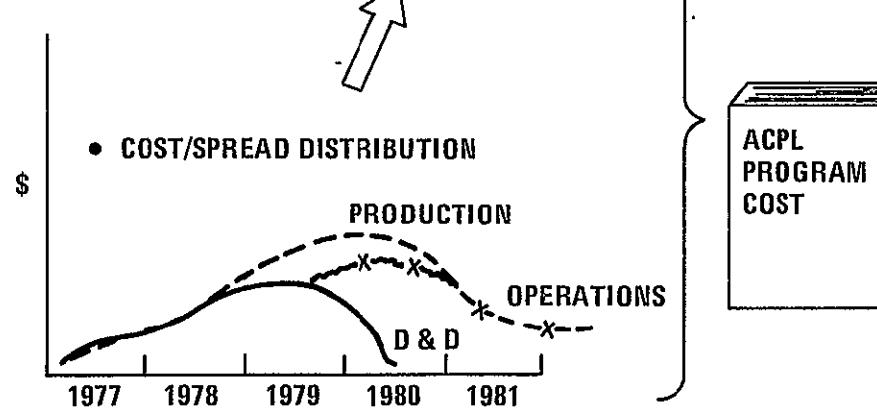


- LOW COST APPROACHES EVALUATION

DESIGN AND DEVELOPMENT
MANUFACTURING
OPERATIONAL SUPPORT
MANAGEMENT



- EVOLUTIONARY GROWTH COST
CONTINUITY
TECHNOLOGY CARRY-OVER



SECTION 4
SCIENTIFIC REQUIREMENTS OVERVIEW

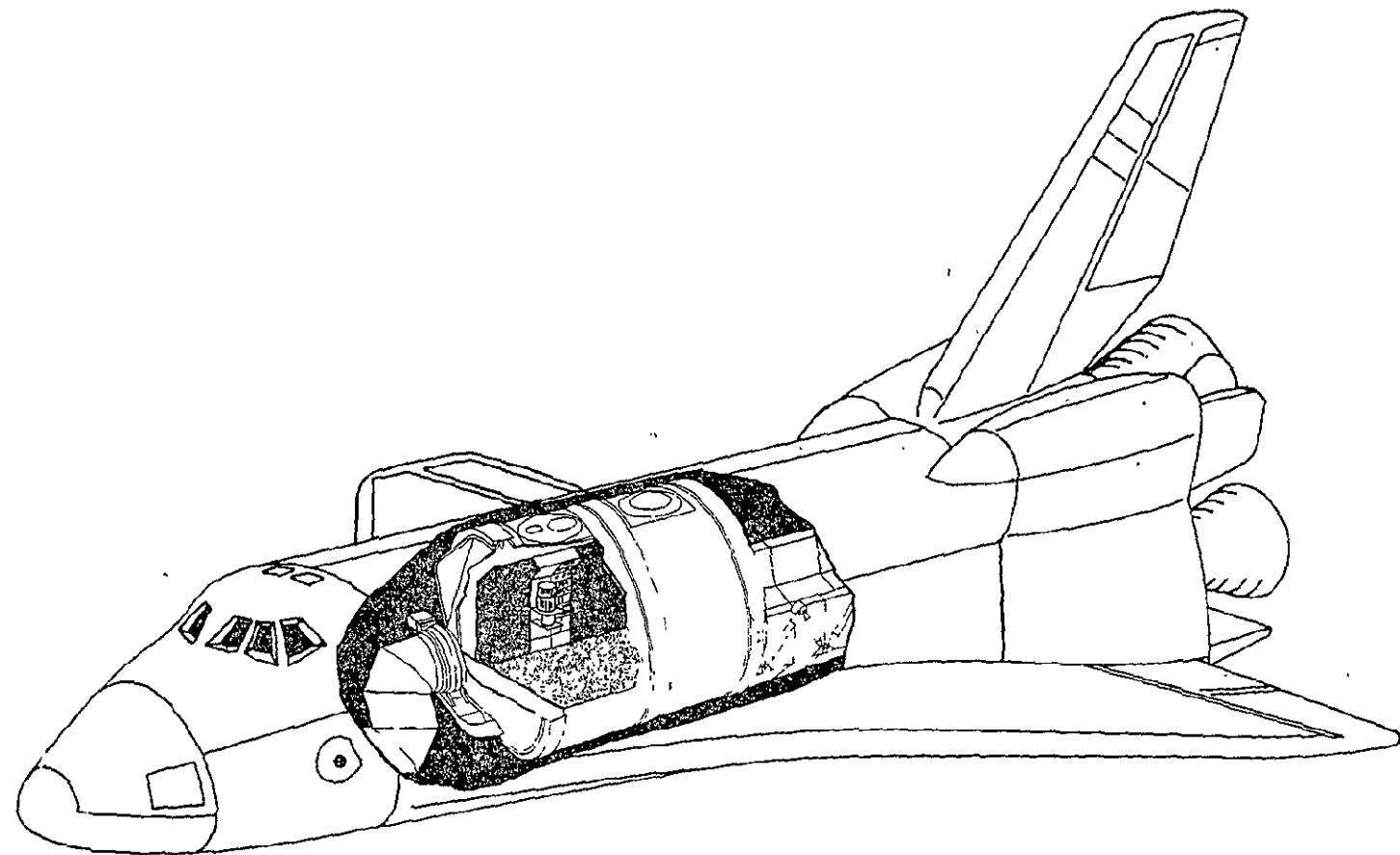
SHUTTLE/SPACELAB

The Shuttle/Spacelab provides a unique opportunity for the performance of cloud microphysics research in a near zero gravity environment. The absence of gravity permits the accomplishment of experiments difficult or impossible to accomplish in a terrestrial laboratory by the extension of experiment observation time. The envisioned ACPL program consists of an Initial ACPL comprised of equipment that can be contained in two standard Spacelab racks and capable of performing significant early research. With evolutionary growth the ACPL will include additional advanced cloud chambers and scientific instruments/equipment capable of performing the broad based experiment program, identified by the prior ACPL studies.

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SPACE
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APPLICATION AREAS FOR WEATHER CONTROL

Man has expressed the desire to avoid, modify, deter or control various elements of weather. The facing page lists a few of the major weather phenomena which cause loss of life and hundreds of millions of dollars damage each year.

Meteorology is directed toward understanding these weather elements. Recently greater emphasis has also been placed on defining the inadvertent, as well as the advertent, effects on weather of mans thermal, particulate and trace gases generation. The ACPL program will aid in gaining knowledge of cloud micro-physical processes by complementing and supplementing terrestrial research into these problem areas.



APPLICATION AREAS FOR WEATHER CONTROL

MAN'S PROBLEM	WEATHER MODIFICATION SOLUTION
HAILSTONE DAMAGE	RESTRICT CLOUD MATURITY, LESSEN HAILSTONE ITERATIONS
REDUCED VISIBILITY DUE TO FOG	DISSIPATE FOG, CLEAR AREAS WITH EXCESSIVE PARTICULATES
INTENSE AND CRIPPLING SNOWFALLS	REDISTRIBUTE PRECIPITATION, CONTROL BUILDUP
INSUFFICIENT WATER FOR IRRIGATION	INCREASE SNOWPACK AND CONTROL RUNOFF
TORNADO DAMAGE AND LOSS	INHIBIT THUNDERSTORM MATURING, CREATE CELL COMPETITION
HURRICANE DAMAGE	REDUCE WIND FIELD, STORM TIDES AND SURGES
LIGHTNING INDUCED FOREST FIRES	REDUCE CLOUD POLARIZATION AND CHARGE BUILDUP

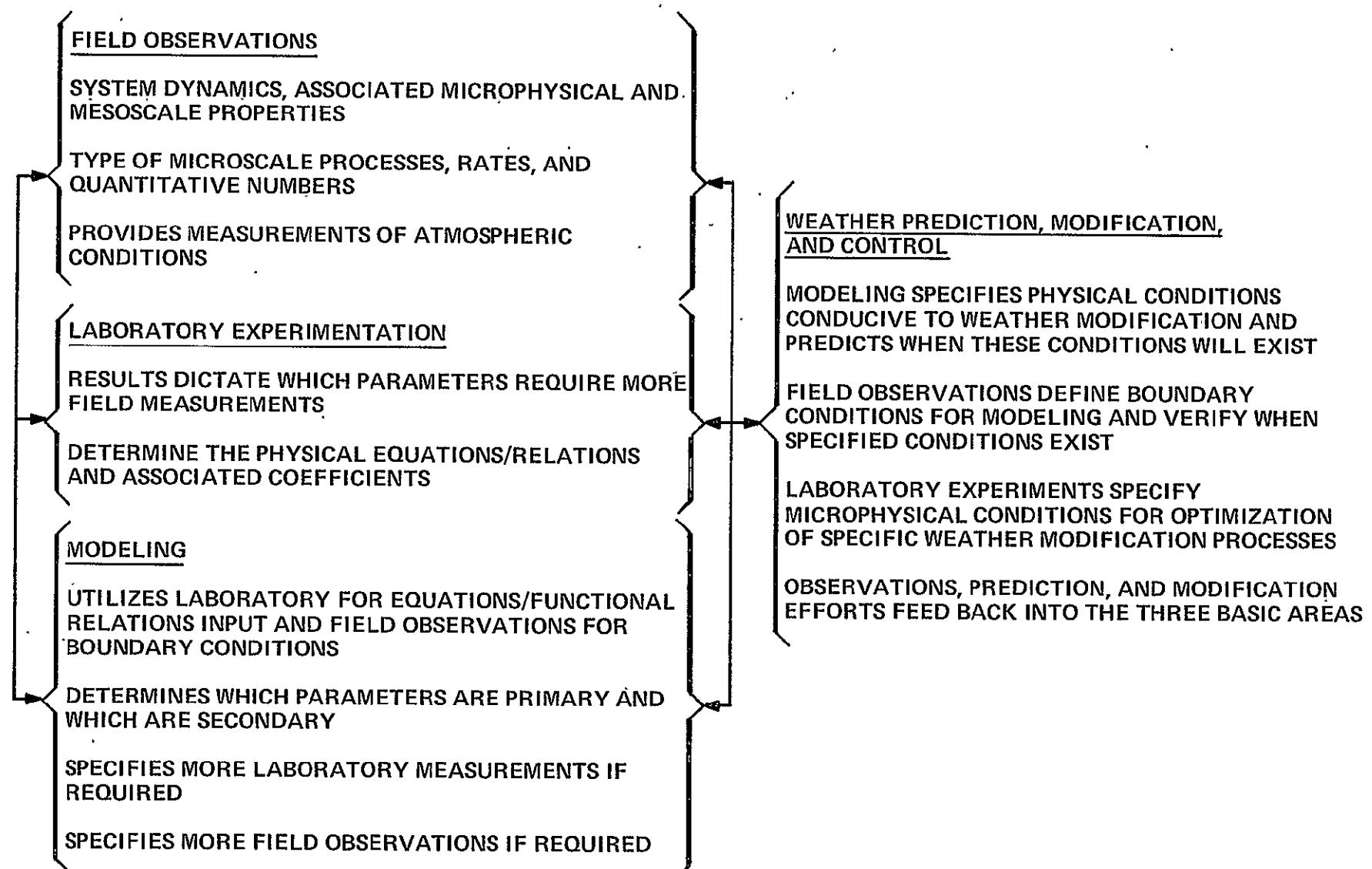
METEOROLOGY DISCIPLINE INTERPLAY

Significant efforts within the broad scope of meteorology have been directed toward the objectives of weather prediction, modification and control. The facing page illustrates some of the interplay among several of the areas of meteorology that contribute to the applications objectives of prediction and control. Field observations of actual weather conditions, modeling of discrete weather processes, and controlled laboratory experimentation are all necessary and interdependent elements of meteorology research.

All of these areas of meteorology, as well as others such as climatology, provide direction and input into weather forecasting, modification and control. Within this complex realm of environmental sciences, laboratory experiments are directed toward the study of microphysical phenomena along with scaled and/or modeled mesoscale (e.g., mountain induced atmospheric waves) and macroscale (e.g., atmosphere and ocean circulation patterns) experiments.

The past forty years have encompassed much progress toward understanding the microphysics of the atmosphere. Yet certain vital aspects of atmospheric microphysics have evaded or defied delineation due to the continual presence of gravitationally induced effects which obscure primary facets of the processes. Recent accomplishments of man in space have provided a new and unique approach to the study of some of these evasive processes. "Zero-gravity" can help distinguish between competing phenomena by the elimination or minimization of certain interferences (e.g., falling droplets) which hamper observation and advancement in these areas.

METEOROLOGY DISCIPLINE INTERPLAY



PRECIPITATION ELEMENTS AND PHYSICAL PROCESSES

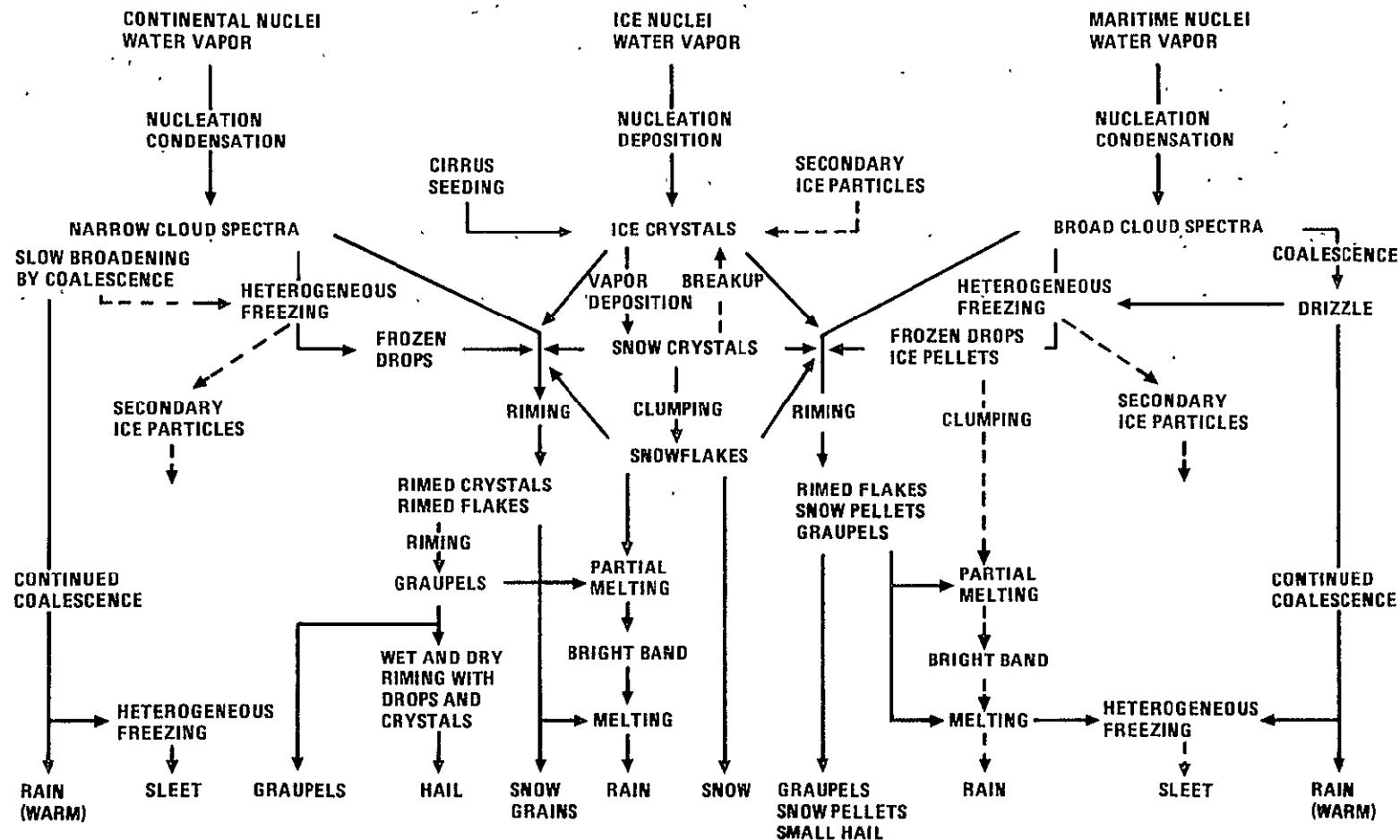
Precipitation is a result of the complex interaction of many processes which often occur in a way which defies delineation within actual clouds. Subtle differences have been observed, (e.g., maritime clouds have a broader droplet size spectra than continental clouds and certain contributions to this difference are known). A full understanding of these differences and their subsequent consequences are not available.

The precipitation processes pictorially presented on the facing page can be grouped into four basic areas which must be better understood before improved modeling and weather prediction and definitive modification can occur. These areas are nucleation, growth, scavenging and electrical charge separation. The laboratory approach to the understanding of these processes is one of separation and isolation of individual processes when possible to provide a tractable research objective.



PRECIPITATION ELEMENTS AND PHYSICAL PROCESSES

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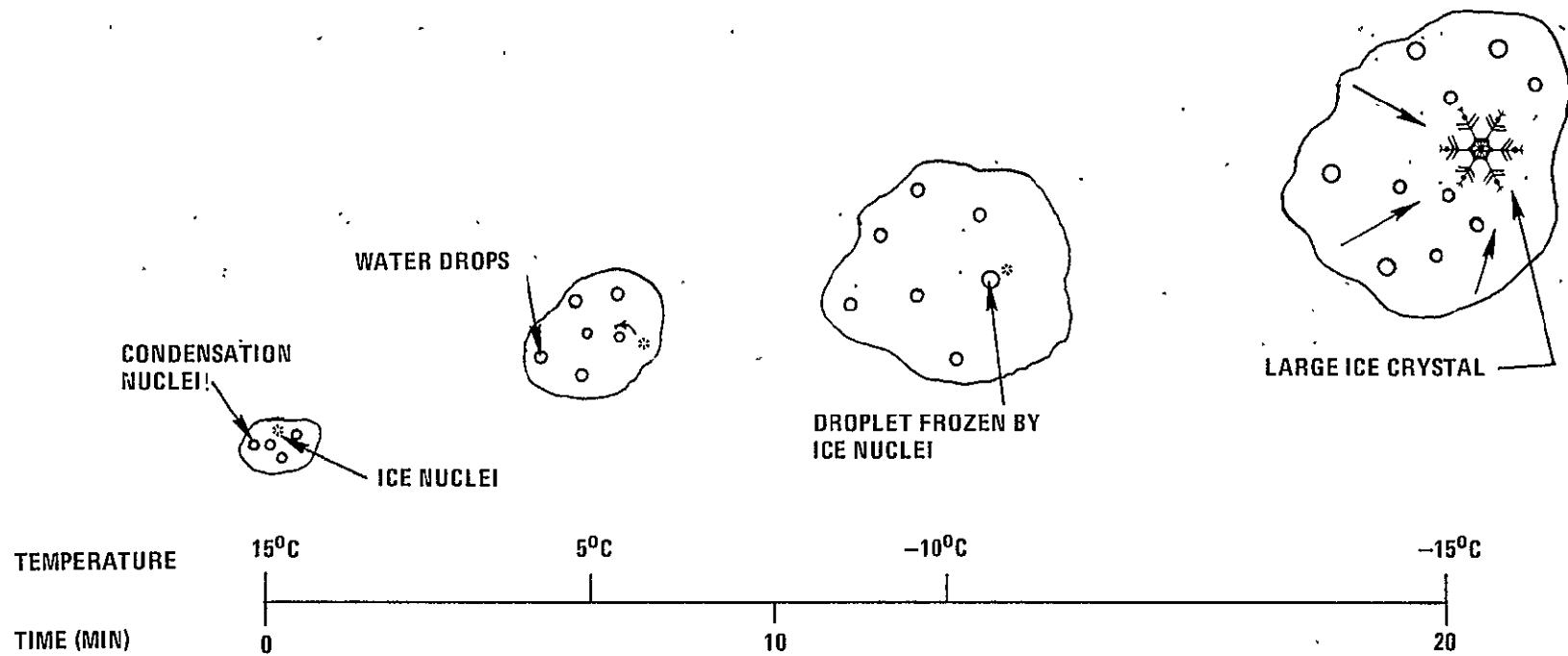
TYPICAL EXPANSION CHAMBER EXPERIMENT

The facing page illustrates some of the phenomena and processes which take place during a natural cloud expansion. The times range from seconds to tens of minutes. Droplets form on condensation nuclei. As the temperature drops due to adiabatic expansion, freezing nuclei are scavenged by supercooled droplets causing freezing. The frozen droplet grows into an ice crystal at the expense of the adjacent unfrozen droplets due to the lower vapor pressure of ice. Each step of this process needs to be studied in detail to aid in the accumulation of cloud microphysics knowledge.



TYPICAL EXPANSION CHAMBER EXPERIMENT

PROCESS: ADIABATIC CLOUD EXPANSION INVOLVED IN A CONVECTIVE CLOUD GROWTH CYCLE



PHENOMENA STUDIED

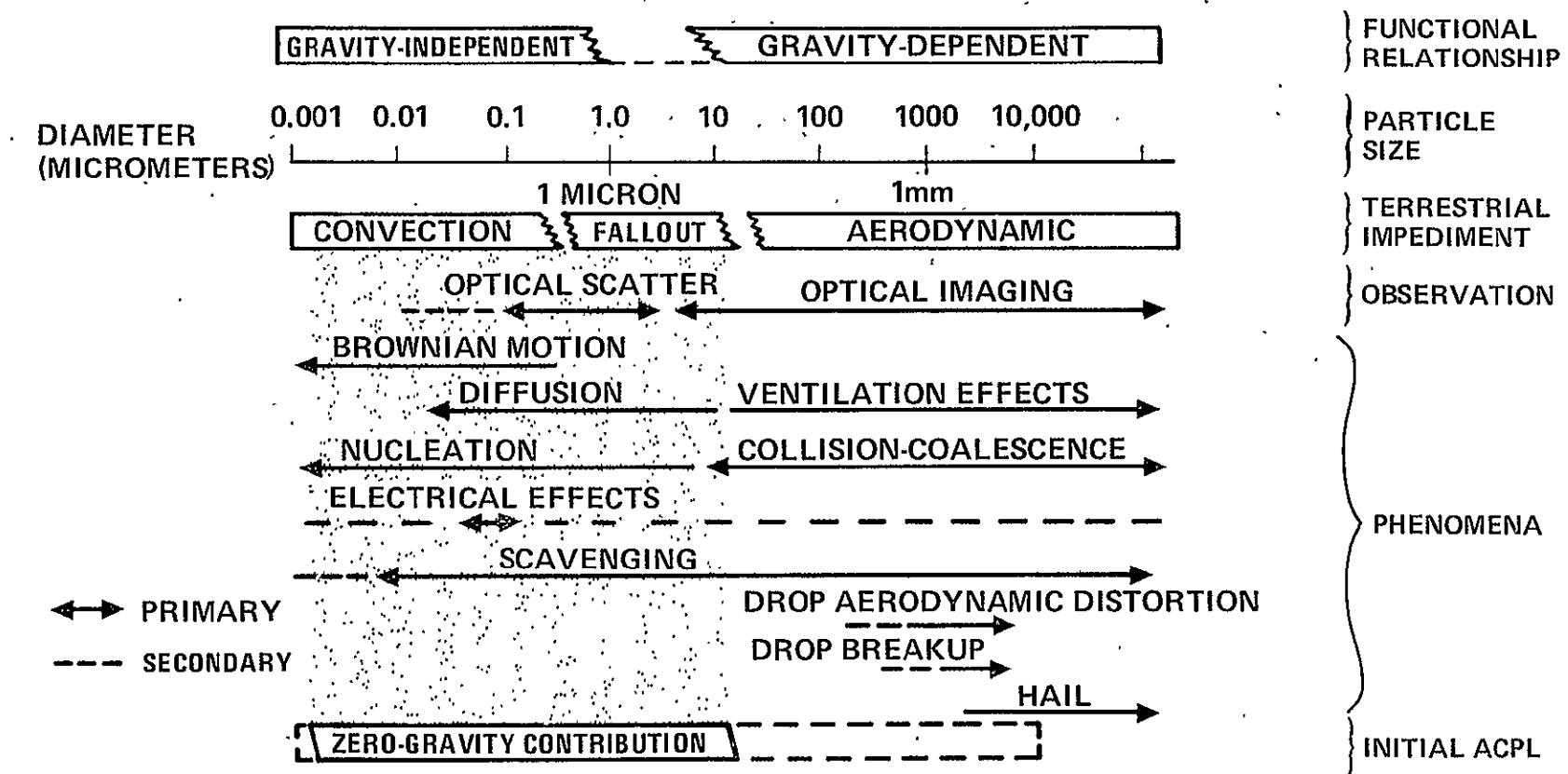
- CONDENSATION NUCLEATION EFFICIENCY
- DROPLET DIFFUSION GROWTH
- SCAVENGING
- ICE NUCLEATION
- ICE MULTIPLICATION
- DROPLET-ICE CRYSTAL INTERACTIONS
- ICE CRYSTAL GROWTH HABIT

ZERO-GRAVITY CLOUD PHYSICS APPLICATIONS

Atmospheric cloud physics involves particles from submicrometer to centimeter in size. Gravity superimposed effects are convection, fallout and aerodynamics which obscure other phenomena in the ranges indicated in the figure. The low-gravity environment promises to be most useful in the shaded region which is also the area toward which the initial ACPL program has been directed. Warm processes are often easier to pursue while ice processes rank higher in the need-to-know but are much more complex. Spacelab capability will influence the specification of experiments and experiment ranges which can be accommodated.



ZERO-GRAVITY CLOUD PHYSICS APPLICATIONS

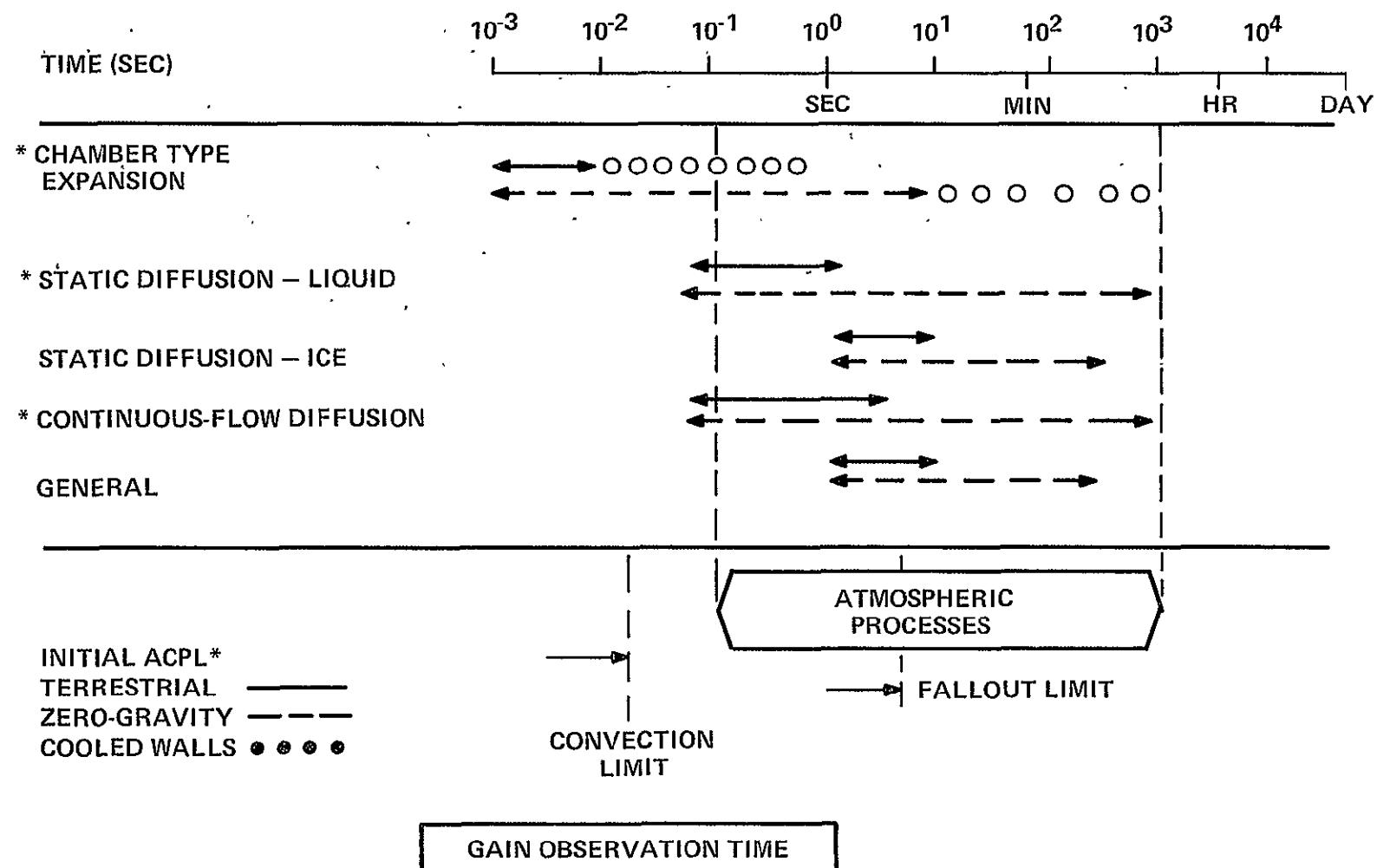


ACPL CLOUD CHAMBER UTILIZATION TIMES

Atmospheric processes range from subsecond to tens of minutes. Various chambers that are used to observe discrete events are restricted in the terrestrial laboratory by gravity induced convection and fallout. Special wall cooling techniques have promised to extend the observation times yet these times fall short of the desired duration. Larger chambers and buildings as well as field observations have provided longer times but mean measurements of multiple processes usually result thus requiring an untangling and interpretation of the results. Therefore, the Spacelab low-acceleration environment will extend the chamber utilization time and provide new insite to some unresolved phenomena and processes.



ACPL CLOUD CHAMBER UTILIZATION TIMES



ACPL EXPERIMENT PROGRAM LISTING

Previous considerations of cloud physics problems and the low-acceleration environment has resulted in a list of experiments which can potentially benefit in varying degrees from the unique Shuttle/Spacelab opportunity. The list is not in a priority order (the priority and low-acceleration requirements will vary as some problems are resolved and new areas are revealed). The proposed initial ACPL experiment areas are indicated on the facing table. Also marked are those experiments which can be partially investigated with the temperature range provided by the Initial ACPL.



ACPL EXPERIMENT PROGRAM LISTING

EXPERIMENT CLASS NO.	EXPERIMENT CLASS TITLE	DESIGNATION
*	CONDENSATION NUCLEATION	CN
**	ICE NUCLEATION	IN
**	ICE MULTIPLICATION	IM
**	CHARGE SEPARATION	CS
**	ICE CRYSTAL GROWTH HABITS	ICG
**	SCAVENGING	S
**	RIMING AND AGGREGATION	RA
**	DROPLET ICE CLOUD INTERACTIONS	DIC
**	HOMOGENEOUS NUCLEATION	HN
**	COLLISION INDUCED FREEZING	CIF
**	SATURATION VAPOR PRESSURE	SVP
*	ADIABATIC CLOUD EXPANSION	ACE
*	ICE NUCLEI MEMORY	INM
*	TERRESTRIAL EXPANSION CHAMBER EVALUATION	ECE
**	CONDENSATION NUCLEI MEMORY	CNM
**	NUCLEI MULTIPLICATION	NM
**	DROP COLLISION BREAKUP	DCB
**	COALESCENCE EFFICIENCIES	CE
*	STATIC DIFFUSION CHAMBER EVALUATION	SDC
*	UNVENTILATED DROPLET DIFFUSION COEFFICIENTS	UDD

* BASELINE

** RESTRICTED PORTIONS

PRELIMINARY EVOLUTIONARY GROWTH CONCEPT

The evolutionary growth concept established as a "point-of-departure" for the ACPL Study is shown on the facing page. This concept identifies five major growth steps in the evolutionary growth process to a Full Capability ACPL. The equipment identified for each growth increment are for scientific equipment subsystems only. In actuality, both the baseline Initial ACPL and the evolutionary growth steps will be modified by the scientific functional requirements and the programmatic constraints. The format shown provides a concise representation of options available for incorporating growth.



SPACE DIVISION

PRELIMINARY EVOLUTIONARY GROWTH CONCEPT

EXPERIMENTAL

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EQUIPMENT COMPLEMENT

BASELINE

1

2

3

4

5

GROWTH INCREMENTS

* MFSC – REQUIREMENT FOR BASELINE

****MFSC – NO REQUIREMENT FOR BASELINE**

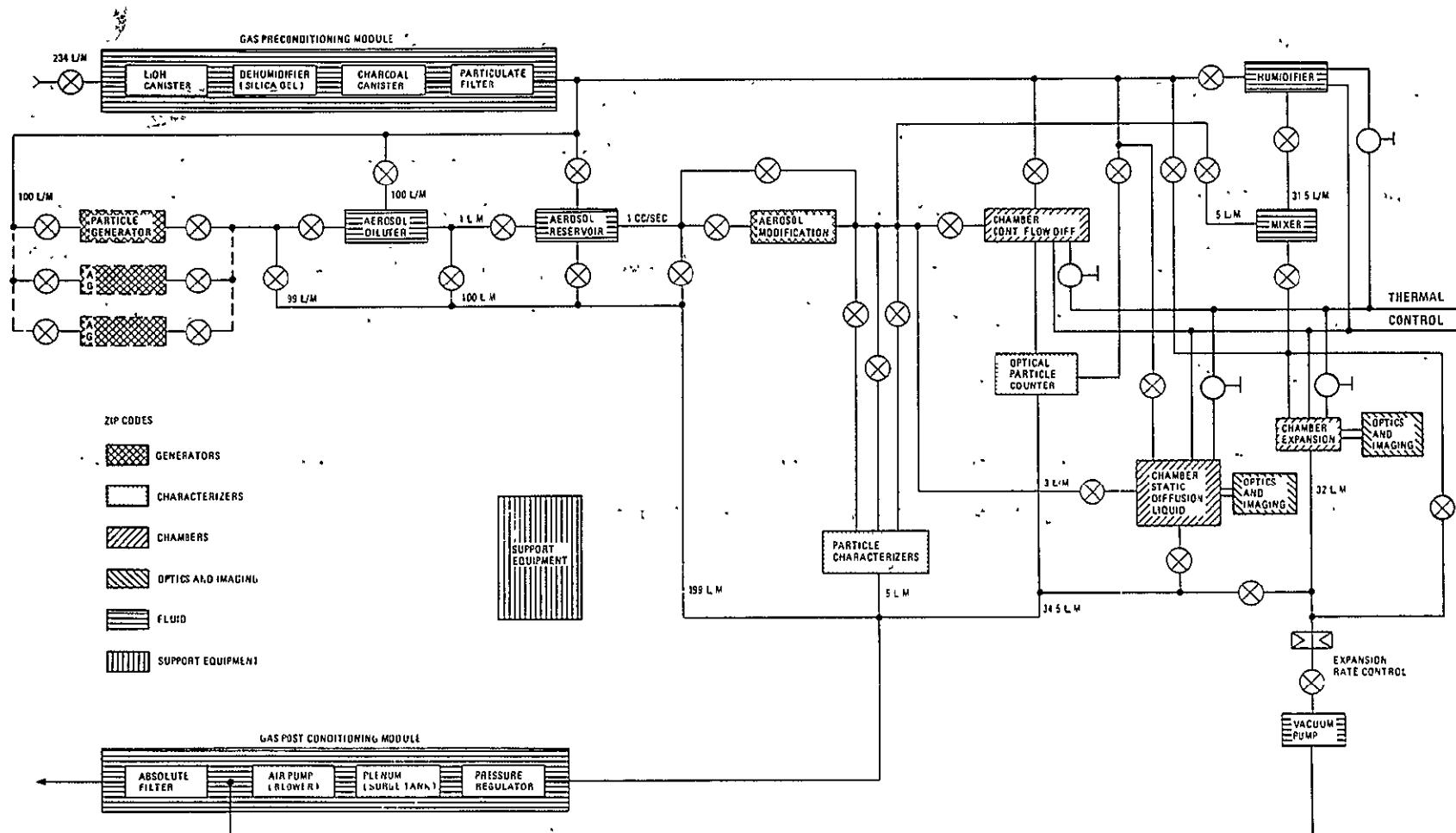
INITIAL ACPL BLOCK DIAGRAM

The block diagram for the Initial ACPL is shown on the facing page. ACPL will use Spacelab atmosphere as the air supply purifying it to experimentation requirements and reconditioning it after experimentation (to requirements specified for Spacelab) prior to reinjection into the cabin. Major operational capability features are shown by the placement of the scientific equipment and the multiple flow paths provided to accommodate anticipated experiment operations. The scientific equipment and flight support subsystem interfaces, internal to the ACPL, are identified. It should be noted that only flight support subsystems (those flown on all missions) interface with Spacelab.



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INITIAL ACPL BLOCK DIAGRAM



REQUIREMENTS

INITIAL ACPL CHAMBERS

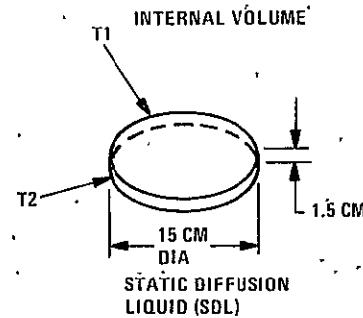
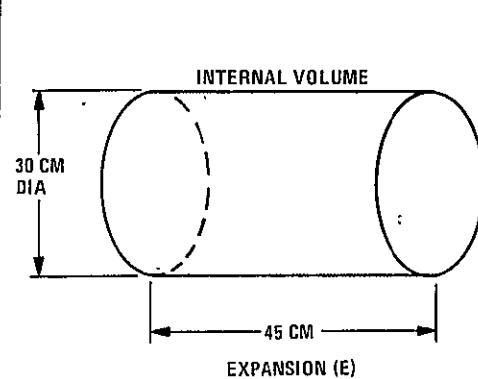
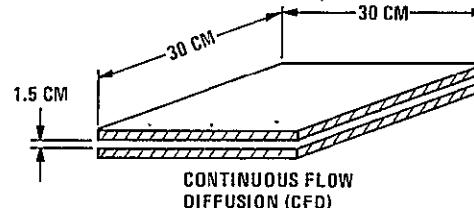
The continuous flow diffusion (CFD) and the expansion (E) chambers have been identified for initial ACPL missions. In addition inclusion of the static diffusion liquid (SDL) must be based on both scientific requirements and the cost impact to the initial ACPL. The geometry of each chamber is determined by considering physical and phenomenological factors (e.g. wall effects and phoretic forces). The general requirements for pressure, relative humidity, temperature and activated nuclei concentration are shown on the facing page. The numerical values in parenthesis were assumed or inferred for the Baseline ACPL while the other value were specified in the NASA/MSFC Initial ACPL Requirements document, dated 1 December 1975.

The temperature and pressure tolerances are cost drivers which must be given carefull consideration when matching experiment objectives with chamber requirements.



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**REQUIREMENTS
INITIAL ACPL CHAMBER**



TECH STATUS COMMERCIAL OR LAB	T ₂ < T ₁ LIQUID SURFACES OUTPUT - SIZE DISTRIBUTION CONDENSATION NUCLEATION	ISO THERMAL HYDROPHOBIC SURFACES OUTPUT - NUMBERS (MEAN SIZES) CLOUD SIMULATION	T ₂ < T ₁ LIQUID SURFACES OUTPUT - NUMBERS (MEAN SIZES) CONDENSATION NUCLEATION
PRESSURE RANGE TOLERANCE	NEAR S/L AMBIENT ABS. \pm 15 mb REL $(\pm 1$ mb) RATE 0.01 mb/SEC	400 mb to 1013 mb ABS. \pm 0.5 mb REL \pm 0.1 mb	NEAR S/L AMBIENT ABS. $(\pm 15$ mb) REL ± 1 mb
RELATIVE HUMIDITY TOLERANCE	100 TO 103% ABS. \pm 0.03% REL. \pm 0.01%	75 TO 99% (INITIAL) COMPUTED	100 TO 103% ABS. (± 0.02) REL (± 0.01)
TEMPERATURE TOLERANCE	15 TO 25°C ABS. (0.3) REL 0.01 (0.1)	-25 TO +25°C (\simeq 0 TO +25°C) ABS \pm 0.005 TO 0.01 REL \pm 0.02 TO 0.15	< 0°C TO > 0°C (0 TO 25°C) ABS \pm 0.03 REL \pm 0.01
$\Delta T = (T_1 - T_2)$ NUCLEI CONCENTRATION	0 TO 10°C (10 TO 1000 NUCLEI/CM ³)	- 10 - 1000 PARTICLES/CM ³	0 TO 10°C (10 TO 1000 PARTICLES/CM ³)

T, P TOLERANCES ARE COST DRIVERS

PARTICLE DETECTORS AND CHARACTERIZERS

The optical particle counter satisfies the data detection requirements of the continuous flow diffusion chamber for droplets between $0.3\mu\text{m}$ and $10\mu\text{m}$ diameter. Aerosol particles below this size can be classified with the Electrical Aerosol (size) Analyzer. A "hard copy" or sample for later electron microscope evaluation can be obtained using the Electrostatic Precipitator Sampler. The above instruments are available commercially and require design modifications to be low-g compatible (e.g., replacement of ball flowmeters by thermal flowmeters), in addition to modifications necessitated by manned space flight.



PARTICLE DETECTORS AND CHARACTERIZERS

REAL OPTICAL NUMBERS	SIZE	MASS	TIME	SIGNATURE	SIZE RANGE (μM)	TYPE
P	P	S		✓		OPTICAL PARTICLE COUNTER
P	—	—		✓		CONDENSATION NUCLEUS COUNTER
P	P	S	—			MICROPOROUS FILTER
—	—	P	✓			QUARTZ CRYSTAL MASS MONITOR
P	P	S	—			CASCADE IMPACTOR
P	P	S	✓			ELECTRICAL SIZE ANALYZER
P	P	S	—			ELECTROSTATIC PRECIPITATOR SAMPLER
—	—	—	✓	✓		SCATTEROMETER
P	P	S	✓	✓		LIQUID WATER CONTENT METER
P	P	S	✓	✓		DROPLET SIZE DISTRIBUTION METER
				✓		OPTICAL DEW POINT HYGROMETER
				✓		ELECTRICAL DEW POINT HYGROMETER
P = PRIMARY		INITIAL ACPL		INITIAL ACPL		
S = SECONDARY		<p>10⁻² 10⁰ 10² 10⁴</p> <p>DIAMETER (μM)</p>				

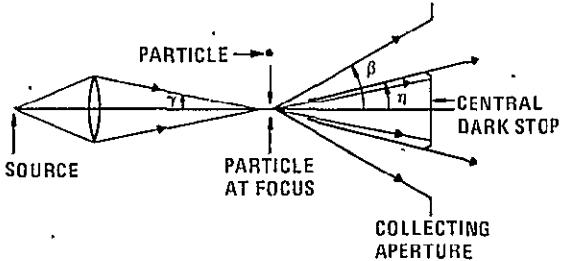
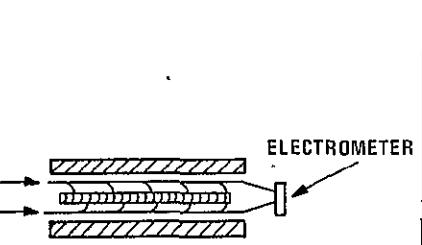
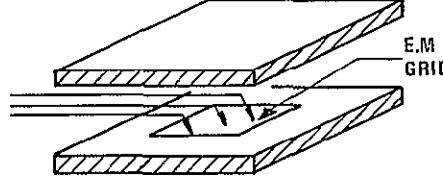
REQUIREMENTS
INITIAL ACPL PARTICLE DETECTORS AND CHARACTERIZERS

The instruments shown in the facing chart are available commercially and have seen several years of laboratory and field operation. Some optical counters and the Electrical Aerosol Analyzer contain ball type flowmeters which would be replaced by hot-film thermal flow sensors. In addition, the instruments must be reconfigured into a Spacelab rack compatible format with emphasis on modularity for mission to mission flexibility.

The primary impact of these sensors on the ACPL relates to the sampling volume and concentration each sensor must process to provide a specified level of readout accuracy, thus impacting the aerosol reservoir sizing. Experiment timeline requirements as to experiment duration and the number of samples required must be known for the assessment of the reservoir volume.



REQUIREMENTS INITIAL ACPL PARTICLE DETECTORS AND CHARACTERISTICS

				
		OPTICAL PARTICLE COUNTER METHOD – OPTICAL SCATTERING DATA – SIZE DISTRIBUTION FORM – DIGITAL STORED COMMERCIAL	ELECTRICAL AEROSOL ANALYZER METHOD – PARTICLE MOBILITY DATA – SIZE DISTRIBUTION FORM – ANALOG STORED COMMERCIAL	ELECTROSTATIC PRECIPITATOR SAMPLER METHOD – ELECTROSTATIC PRECIPITATOR DATA – SIZE DISTRIBUTION FORM – AEROSOL SAMPLE COMMERCIAL
SIZE RANGE		$0.3 < d < 5 \mu\text{m}$	$10^{-3} < d < 10 \mu\text{m}$	$2 \times 10^{-2} < d < 10 \mu\text{m}$
SIZE RESOLUTION		(~ 10 INCREMENTS)	10 INCREMENTS	SAMPLING PERIOD & ELECTRON MICRO- SCOPE DEPENDENT
NUMBER RESOLUTION		(< 5% OF READING)	FACTOR OF 2 OR BETTER	SAMPLING PERIOD
COUNT RANGE		$\leq 10^3 \text{ pps}$	—	—
FLOW RATE		$20 - 100 \text{ CM}^3 \text{ SEC}^{-1}$	4 lpm	4 to 10 lpm
SAMPLE VOLUME		6 l	TBD	TBD

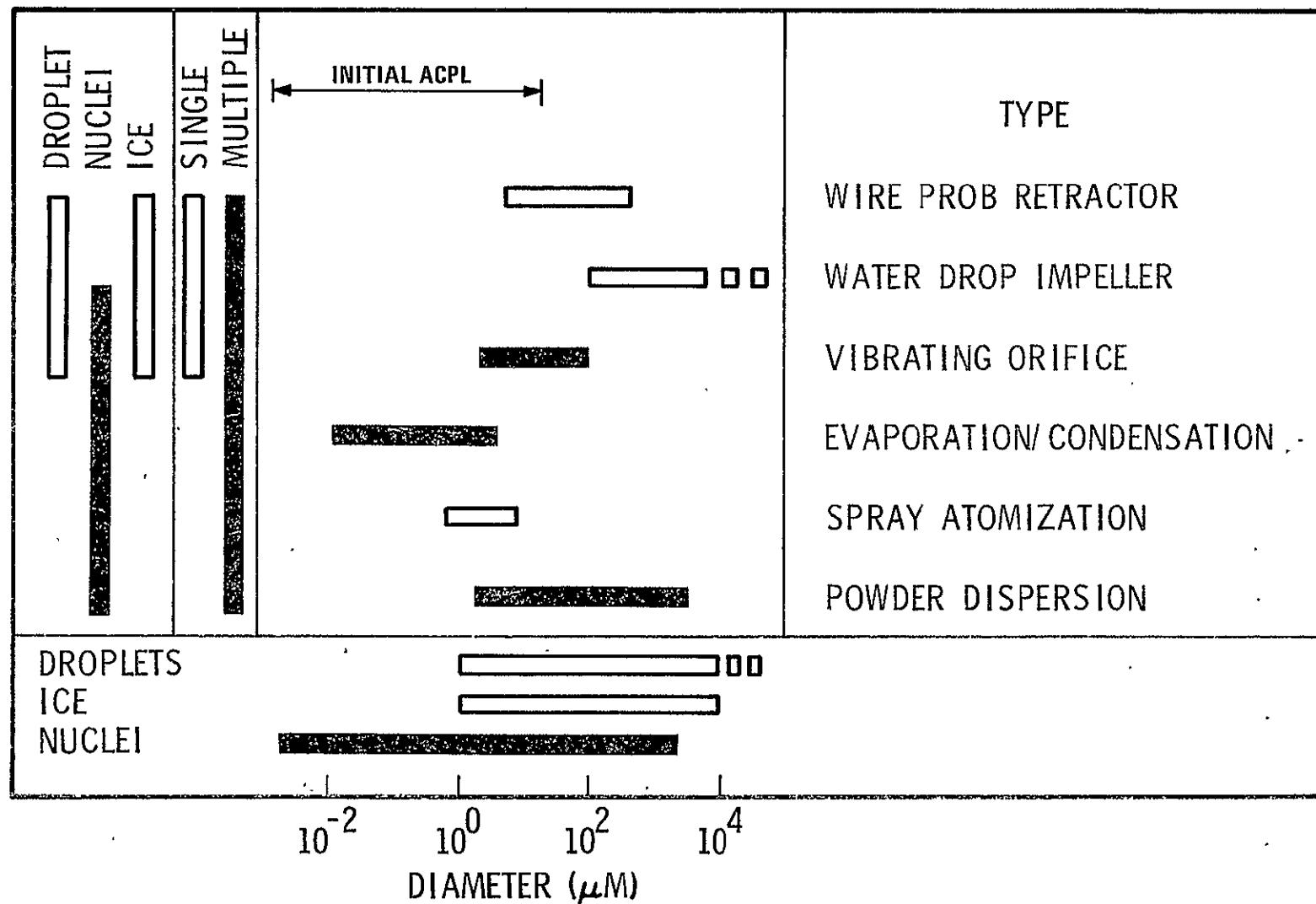
SAMPLING IMPACTS RESERVOIR VOLUME

PARTICLE GENERATORS

The initial ACPL requirements specify particle diameters between the useful limits of $10^{-3}\mu\text{m}$ and $10\mu\text{m}$. A polydispersed aerosol is implied with at least the NaCl aerosol concentration restricted to particles less than $0.05\mu\text{m}$ diameter. The evaporation/condensation (hot wire or equivalent) technique can provide NaCl and AgI aerosols. Latex spheres are normally dispersed by a vibrating orifice generator or spray atomizer while the Teflon particle aerosol must be produced by a dry powder dispersion technique. The aerosols of $(\text{NH}_4)_2\text{SO}_4$ and H_2SO_4 would best be generated using photo-chemical methods with a combination of appropriate gases and ultra-violet light as required. Compatability between aerosols must be considered if more than a single type is required per mission. For example Teflon and NaCl might be compatable without requiring extensive cleaning in orbit.



PARTICLE GENERATORS



REQUIREMENTS

PARTICLE GENERATION AND CONDITIONING

The hot-wire generates a very large number of particles in a short time and thus the aerosol must be diluted to prevent coagulation. Additionally, powders are difficult to disperse and are generally restricted to particle diameters greater than $0.5\mu\text{m}$. The vibrating orifice generator will provide highly monodispersed latex spheres but is restricted to particles greater than a few tenths of micrometers in diameter. The diffusion battery (several methods are available) can be used to narrow and shape the nuclei distribution.

In addition to the consideration that will be given to the individual generator operational requirements, a very significant part of this analyses will be directed toward the compatibility of the generator outputs and the storage and chamber input requirements. Aerosol integrity is always threatened by coagulation and transport losses. Coagulation losses can be minimized by dilution to a level compatible with experiment requirements. In addition, air humidification and aerosol inclusion provide further stringent requirements on how and at what concentration the aerosol must be maintained. Aerosol transport losses, while independent of tube diameter for fixed quantity flow, can be minimized by short tubing length and restricting the use of bends.

Experiment timelines (duration, quantity, concentration, size distribution), number of samples and sample integrity specifications have an extensive impact on aerosol dilution and transport. Thus experiment objectives and representative timelines are highly desirable.



SPACE
DIVISION

REQUIREMENTS
PARTICLE GENERATION AND CONDITIONING



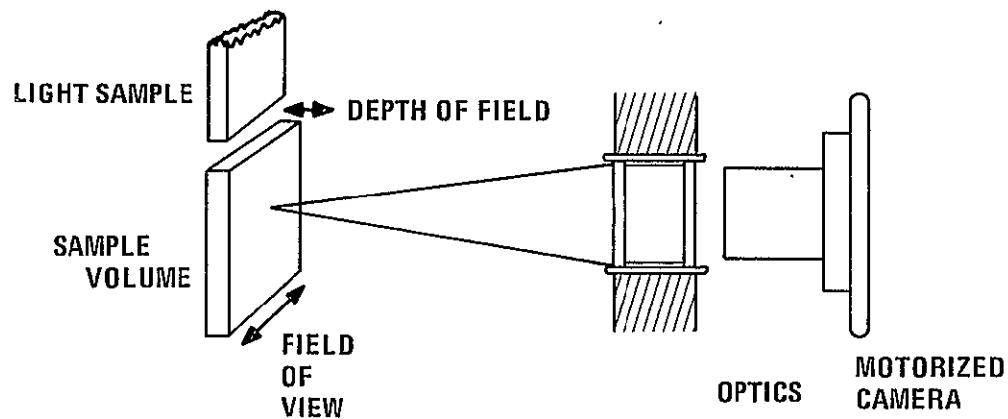
	EVAPORATION/CONDENSATION METHOD - HOT WIRE FORM - SOLID AND LIQUID	POWDER DISPERSION METHOD - PNEUMATIC FORM - SOLID	VIBRATING ORIFICE METHOD - FLUID DYNAMIC FORM - LIQUID AND SOLID	AEROSOL CONDITIONING (DIFFUSION BATTERY) METHOD - DIFFUSION/ INERTIAL FORM - NARROWS SIZE DISTRIBUTION
SIZE RANGE	$<10^{-2}$ TO $\sim 1 \mu\text{m}$	$> 0.5 \mu\text{m}$	$> 0.5 \mu\text{m}$	$\simeq 0.3 \mu\text{m}$ PEAKS
DISPERSION	POLY TO MODERATE	MODERATE	MONODISPERSE	MODERATE
GENERATION RATE	$>> 10^6/\text{SEC}$	TBD	$\sim 10^5/\text{SEC}$	-
MATCHING GENERATOR OUTPUT TO CHAMBER REQUIREMENTS				
AEROSOL INTEGRITY - DRIVER e.g.: COAGULATION INDUCED CHANGES VERSUS TIME				

REQUIREMENTS
OPTICAL AND IMAGING

Minimum size detection and total sample count error couple with particle concentration constraints define the desired sample volume. Often in opposition to this sample volume requirement are the optical limitations as dictated by such things as chamber geometry (working distances), port size and light intensity. Trades will be made assessing the experiment objectives and optics/imaging capability required. These analyses will establish the window optical properties, the light source characteristics, the light trap configuration, the camera optics specification and the sampled volume as a function of minimum detectable particle size.



REQUIREMENTS OPTICAL & IMAGING



SPECIFIED		UNSPECIFIED	
• PARTICLE DENSITY	10-1000 PARTICLES/CM ³	MINIMUM DETECTABLE SIZE	$\geq 2\mu\text{m}$ DIAMETER
• FRAMING RATE	≤ 1 FRAME/SEC	TOTAL COUNT ERROR BAND	$\leq 20\%$ OF COUNT
• SAMPLING VOLUME ACCURACY	3%		

OPTICAL REQUIREMENTS FUNCTION OF
CHAMBER GEOMETRY AND DATA REQUIREMENTS

RÉQUISITE

HUMIDIFIER

The humidifier will be used to precondition the air to be injected into the expansion chamber.

Numerous physical designs will satisfy the basic requirements but a cost savings can be realized by designing the humidifier around the continuous flow chamber configuration since both have the same basic requirements.

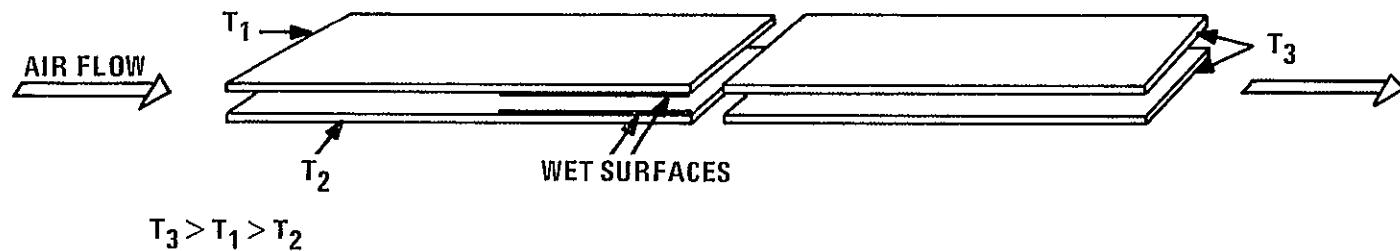
The humidifier will have two stages. The air is first saturated to a dew point as required by the expansion chamber with consideration given to pressure and final temperature of the required conditioned air.

The air is then warmed to the desired final temperature and delivered to the expansion chamber. Note that the aerosol cannot be brought through the humidifier without effecting the nuclei. The proposed procedure is to supply the aerosol at a concentration about 100 times above the desired final level.

Thus the aerosol could be injected into the humidified air just before or just after entering the chamber. If a further reduction in temperature and relative humidity perturbation is required, the aerosol temperature could be preconditioned just prior to mixing.



REQUIREMENTS HUMIDIFIER



SPECIFIED

- AIR TO BE 99.995% OF SPECIFIED RELATIVE HUMIDITY
- FLOW RATES UP TO 1 LITER PER SECOND
- DEWPOINT 0 TO $+35^{\circ}\text{C}$
- PRESSURE $\pm 1.0\text{mb}$ ABSOLUTE

CONDITIONED AIR AND AEROSOL INTEGRITY

REQUIREMENTS
FLUID (AIR/NUCLEI) CONTROL

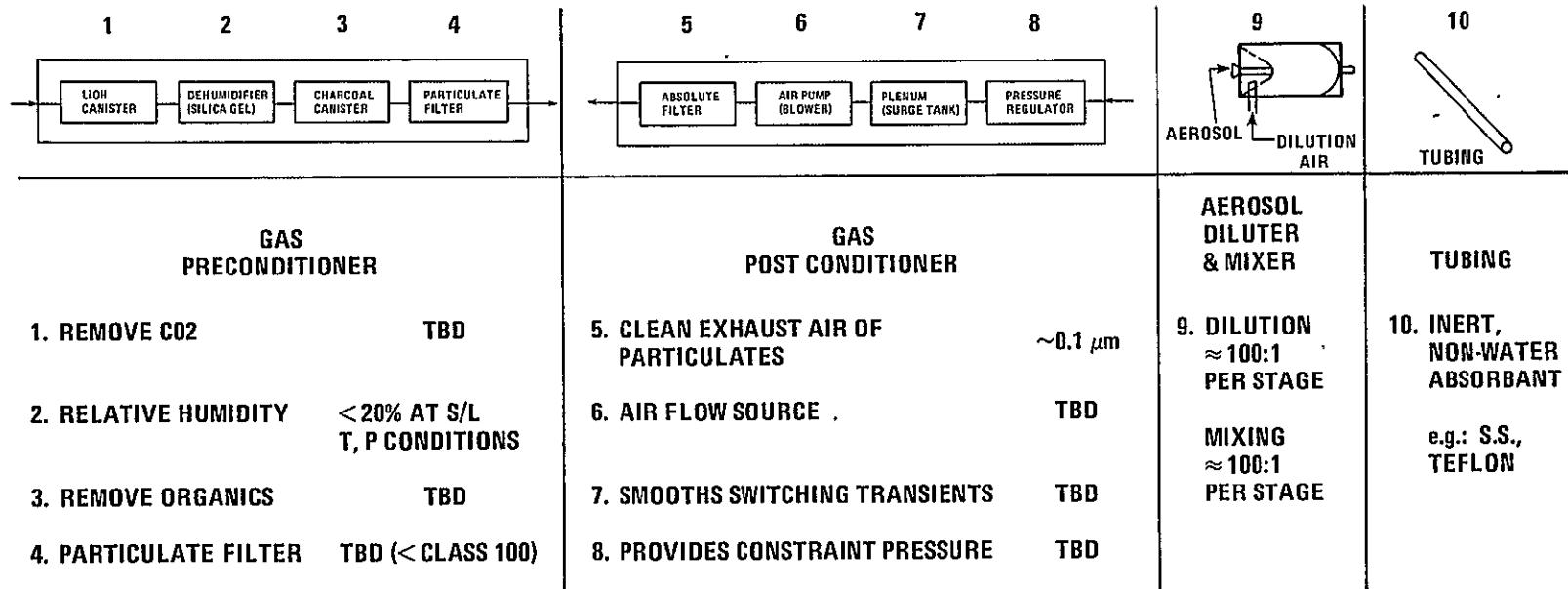
The ACPL will require a source of air free of particle and trace (organic) gases. The proposed approach will be to intake the Spacelab ambient air and condition it to remove specific elements as shown on the facing page. The air is pulled through the ACPL lab system and exhausted back to the Spacelab environment after appropriate filtration. This air source provides the major flow thru the ACPL equipment, being supplemented by separate closed loop sheath flow pumps in certain instruments and by the pump mechanism which provides the controlled expansion.

Additionally the aerosol must be diluted appropriately (while maintaining its integrity) to interface the generators with the storage and experiment requirements. Special consideration must also be given to the tubing which transports the nuclei and the moist air.

Sizing the fluid control elements are highly dependent on the experiment timelines and must also consider the combined characteristics of the chambers, generator and characterizers. Functional tests may be required to fully determine the fluid control requirements.



REQUIREMENTS FLUID (AIR/NUCLEI) CONTROL



SIZING IS FUNCTION OF CHAMBER/GENERATOR/CHARACTERIZER REQUIREMENTS

COMPARISON OF EXPLICIT REQUIREMENTS

Temperature, pressure and cleanliness are major variables which exert direct influence on the scientific equipment. Each must be monitored and in some cases controlled to a degree dictated by the experiment objective. Yet the same variables also can become very significant cost drivers if the state-of-the art is pushed. The experiment requirements do indeed often approach this cost sensitive boundary. Thus each requirement must be carefully weighed as to its absolute necessity and weighed against the Spacelab capability, technology status, experiment specialist training and timeline compatibility. Also all absolute accuracies, which in turn will require NBS traceability, must be carefully delineated. Any given specification will require an even tighter design tolerance in order to assure satisfaction of the requirement.



COMPARISON OF EXPLICIT REQUIREMENTS

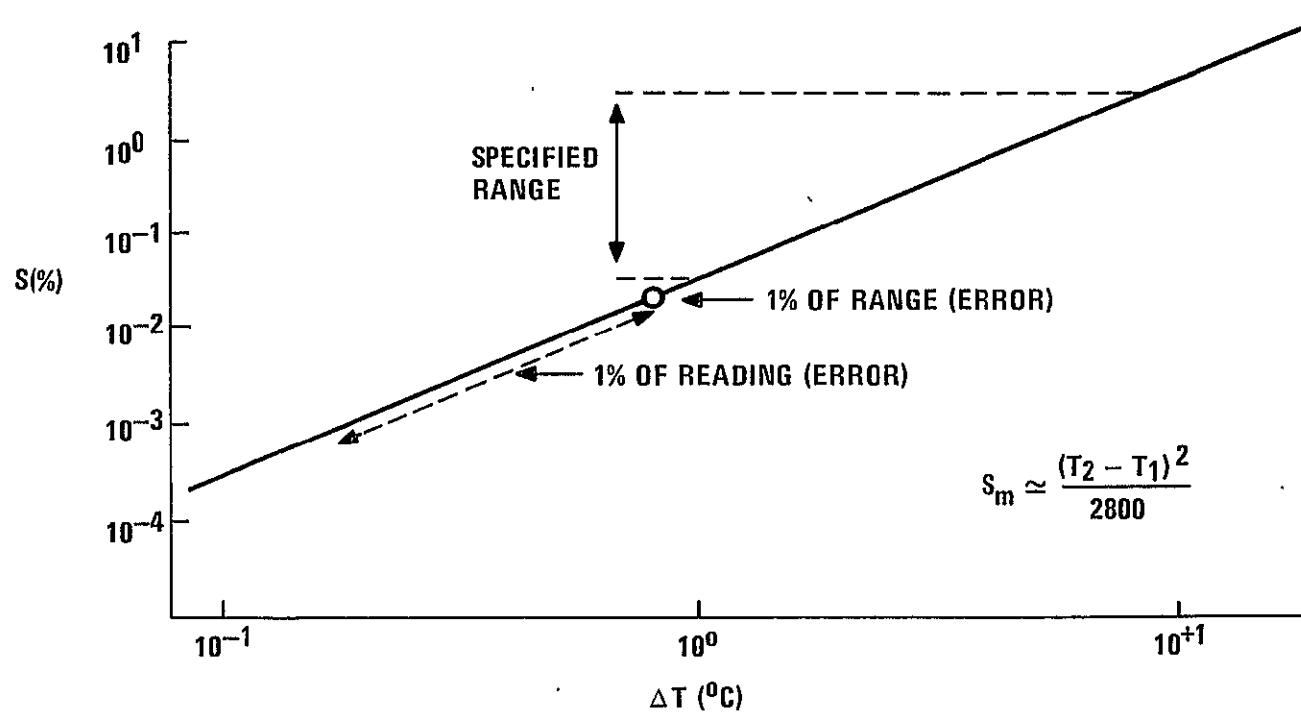
EXPLICIT	BASELINE	DESIGN CONSIDERATIONS
$-25 < T < +25$	$\approx 0 < T < +25$	<ul style="list-style-type: none">• S/L CAPABILITY• TECHNOLOGY STATUS• REQUIREMENTS COMPATABLE
$\pm 0.01 < \Delta T < \pm 0.15^{\circ}\text{C}$	$\Delta T = 0.1^{\circ}\text{C}$	<ul style="list-style-type: none">• GUARANTEED ACCURACY• MEASUREMENT ACCURACY FULL SCALE READING• TECHNOLOGY STATUS
$400 \text{ mb} \leq P \leq 1013 \text{ mb}$	$400 \text{ mb} \leq P \leq \text{S/L AMBIENT} - \Delta$	<ul style="list-style-type: none">• S/L CAPABILITY• SYSTEM CLEANLINESS
$0.05 \text{ mb} \leq \Delta P \leq \pm 1 \text{ mb}$	$\Delta P \leq 1 \text{ mb}$	<ul style="list-style-type: none">• TECHNOLOGY STATUS• REQUIREMENTS COMPATABLE• MISSION COMPATABLE
$dP/dT < 0.01 \text{ mb/SEC}$	TBD	<ul style="list-style-type: none">• S/L CAPABILITY• REQUIREMENTS COMPATABLE
CLEAN (MANUAL) IN ORBIT	PURGE AND FLUSH	<ul style="list-style-type: none">• EXPERIMENT SPECIALIST TRAINING• TIMELINE• S/L CAPABILITY• COMPATABLE AEROSOLS

SUPERSATURATION/THERMAL TOLERANCE CONSIDERATIONS

An example for thermal tolerance consideration for diffusion type chambers is the control of the maximum supersaturation (S_m) between the plates of a diffusion chamber. The adjacent graph indicates the desired range of S_m (%) of 0.05 to 3% supersaturation which in turn requires absolute temperature differences of 1 to 10°C . An error of 1% of full scale for this S_m range would require the temperature difference between the two plates to be read to about 1°C . More desireable, a 1% error of absolute reading would require a differential temperature measurement of about 0.2°C for $S_m = 0.05\%$. Specification of thermal tolerances, in accordance with experiment data accuracy requirements can reduce ACPL equipment cost.



SUPERSATURATION/THERMAL TOLERANCE CONSIDERATION



RESOLUTION OF $S = 0.05\% \pm 0.0005\%$
REQUIRES
 $\Delta T \simeq 1{}^\circ\text{C} \pm 0.2{}^\circ\text{C}$



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